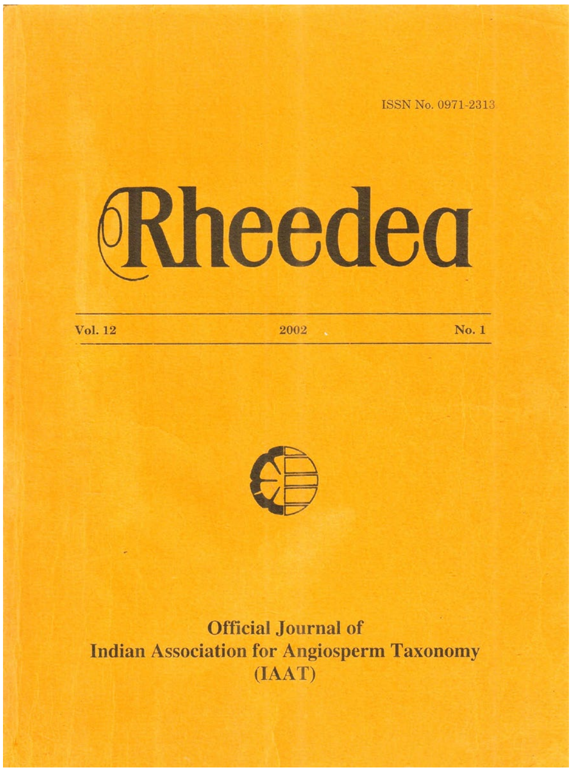
RHEEDEA
Journal of the Indian Association for Angiosperm Taxonomy

Vol. 12(1): 53–72 (2002)
ISSN: 0971-2313 (Print edition)
ISSN: 2582-2438 (Online edition)

Silica bodies and their Taxonomic value in the Sedges of Warangal, Andhra Pradesh

Satyanarayana Reddy P. & T. Rajagopal



How to cite:

Reddy P.S. & T. Rajagopal 2001. Silica bodies and their Taxonomic value in the Sedges of Warangal, Andhra Pradesh. *Rheedea* 12(1): 53-72.

https://dx.doi.org/10.22244/rheedea.2002.12.01.03

Published in print: 30.06.2002 *Published Online*: 01.01.2022

विज्ञान एवं प्रौद्योगिकी विभाग
DEPARTMENT OF SCIENCE & TECHNOLOGY

Published by Indian Association for Angiosperm Taxonomy
This volume of Rheedea is published with partial financial assistance from Department of Science and Technology, Government of India, New Delhi

Rheedea Vol. 12(1): 53-72. 2002

Silica bodies and their Taxonomic value in the Sedges of Warangal, Andhra Pradesh

P. Satyanarayana Reddy and T. Rajagopal
Department of Botany, Osmania University
Hyderabad, Andhra Pradesh – 500 007, India.

Abstract

Silica bodies in the epidermis of various organs of 51 species of Cyperaceae were studied. Cone-shaped silica body is the commonest type and occur in costal cells. These are more frequent on abaxial surfaces of leaf, bract, sheath, glume and culms. Cones are much variable in their number per cell, size, arrangement in the cell, and may be with or without satellites (minor cones) around them. Satellites too, are variable in their size, number and arrangement. Other than cones, several 'atypical' bodies, usually present in inter-costal cells, and restricted to few genera (*Scleria* and *Rhynchospora*) are also observed. Hence the genera and tribes in which these 'atypical' bodies are present can be distinguished from others. Silica body characters are also of diagnostic value to some extent at species level. An account of form, distribution and taxonomic significance of silica bodies is presented.

INTRODUCTION

Cyperaceae are considered to be taxonomically a most difficult group (Metcalfe, 1971). Silica bodies along with other epidermal characters, as revealed by the surface- view studies or through sections were found to be of diagnostic value in many instances and also helpful in the better understanding of the affinities among various taxa of the family (Duval-Jouve, 1873; Pfeiffer, 1921, 1927; Staudermann, 1924; Ahuja, 1962; Mani, 1963; Metcalfe, 1964, 1969, 1971; Metcalfe & Gregory, 1964; Mehra & Sharma, 1965, 1969; Govindarajalu, 1966-1981; Vignal, 1970; Gordon-Gray, 1971; Lee & Oh, 1971; Sharma & Mehra, 1972; Oh, 1974; Le Cohu, 1973; Rajagopal, 1973). Earlier studies on silica bodies including those of Metcalfe (1971) are mostly limited to leaf or culm and sometimes to sheath, whereas in the present work, the silica bodies were studied in all organs of the plant except root. In the present paper, an account of silica bodies present in 51 sedge species belonging to 12 genera with reference to their form, distribution, and the taxonomic importance is presented.

Silica bodies are of widespread occurrence throughout Cyperaceae, with some exceptions (Metcalfe, 1971). Cone-shaped silica body is the commonest type found and usually occur in costal cells, i.e., epidermal cells overlying sclerenchyma that accompanies the vascular bundles of veins. These are developed on the inner periclinal (tangential) wall of the cell, with their bases resting on it and the tip pointed towards the outer periclinal wall (Fig. 1: B,D). In surface view, they appear as a small circle (cone tip) within a large one (base) (Fig. 1: A,C). Very frequently a cone is surrounded by a circle of minor cones, whose tips appear as dots around the main cone (central cone) and are usually referred as 'satellites' for descriptive purposes (Fig.1: E,F). Besides the usual cones, other types of silica bodies are also encountered in various taxa. It may be noted here that silica bodies are not visible unless the peel is treated with phenol crystals.

MATERIALS AND METHODS

All the materials used for the study had been obtained from specimens collected by the authors from Warangal District of Andhra Pradesh as part of floristic study of the area. Mostly, herbarium materials have been used to obtain epidermal peels. But in few cases, materials fixed in formalin-acetic acid-alcohol (FAA) were also used. Herbarium materials when used, are first boiled in water for 5-10 minutes, then few drops of acetic acid were added to soften and to help recovery of the tissues to natural state. Usually the middle portion of the organ such as leaf, bract, sheath (and whole organ in case of glume) was selected for obtaining the peel (Metcalfe, 1971; Rajagopal & Satyanarayana Reddy, 1984). On the peel so obtained a crystal of phenol is placed and gently warmed. The silica material, if present, will be visible as glistening pinkish bodies. The preparations were immediately examined and the observations recorded as the phenol quickly gets crystallised. The terminology used here in describing various forms of silica bodies are mostly after Metcalfe (1971).

The voucher specimens and slides are deposited at Department of Botany, Osmania University, Hyderabad – 500 007 (A.P.) Names of all species studied are listed in the Table 1.

OBSERVATIONS

The distribution pattern of silica bodies in various organs of the taxa are presented in the Table 1. Here, only the salient features of the silica bodies of each genus studied are given and they are as follows:

Explanation to Fig. 1. A-B. One cone per cell (A-surface view, B-sectional view); C-D. Two or more cones per cell (C-surface view, D-sectional view); E-F. Cones with a circle of satellites (E-surface view, F-sectional view); G. Cones with many asymmetrically arranged satellites; H. *Pycreus flavidus* - Sheath (abaxial epidermis) with several asymmetric satellites; I. *Fimbristylis ovata* - Cones with crescent-shaped projections on leaf abaxial surface; J. *F. ferruginea* - Spirally arranged crescent-shaped projections on leaf abaxial surface; K. *Scirpus juncoides* - Several small satellites placed away from main cone on culm; L. *Fimbristylis complanata* - Cones with flat-tips; M-N. 2-peaked cones (M-surface view, N-sectional view); O-P. Cones with many peaks or nodular bodies. (O-surface view, P-sectional view). (All drawings are diagrammatic except H, K, L).

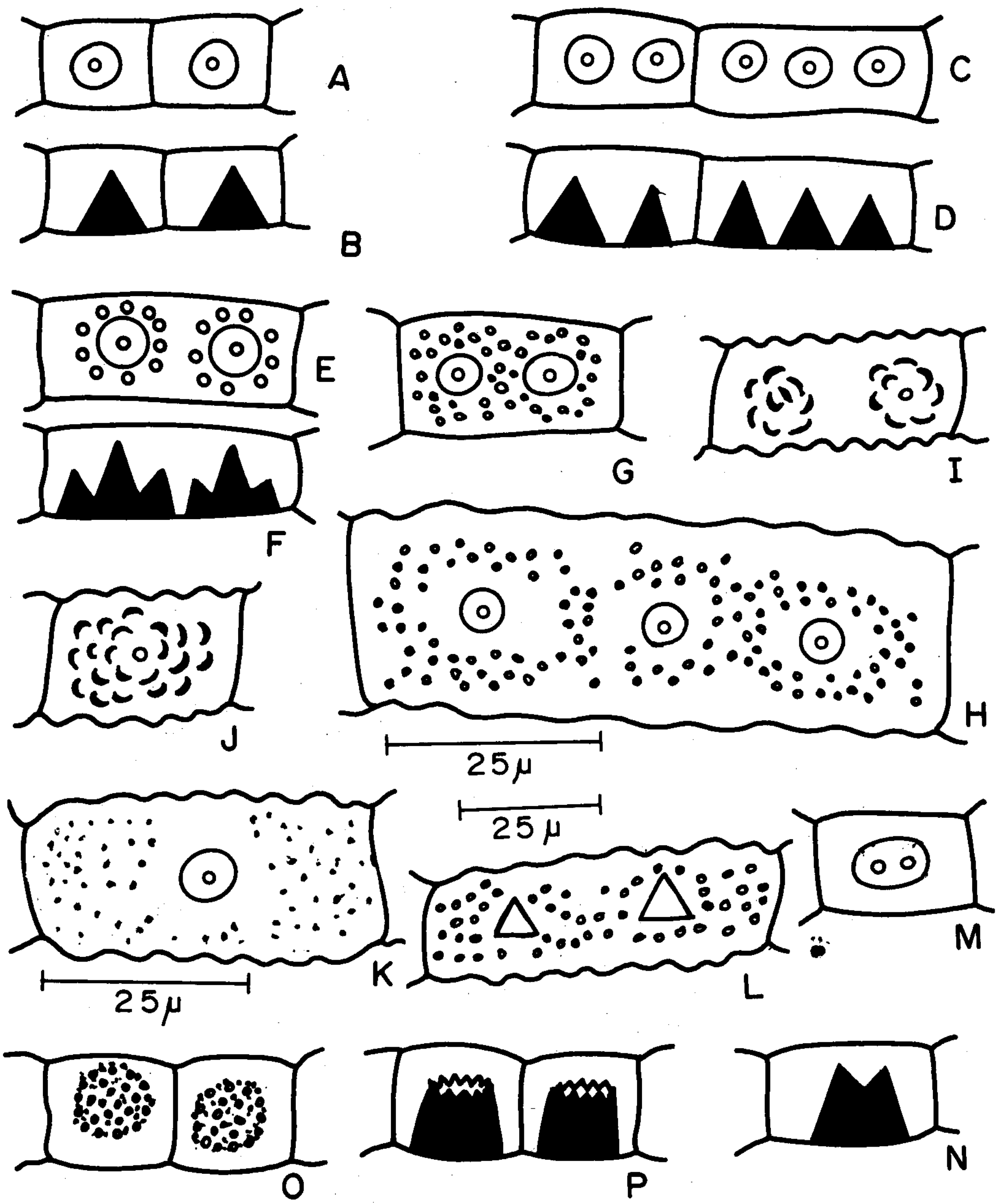


Fig. 1. Distribution of silica bodies in sedges

Bulbostylis Kunth ex Clarke

Apart from normal staellites, crescent-shaped projections around the cones were observed. Unlike the satellites, the crescent-shaped projections tend to be arising on the shoulders of the main cone. These are similar to those of *Fimbristylis ovata* (Fig. 1: I).

Cyperus L., *s. str.*

Silica bodies of cone type are recorded on abaxial surfaces of leaf, bract and sheath of all the 17 species studied. On adaxial surfaces of these organs they may be absent or confined to margins. On leaf and bract abaxial surfaces, maximum development of bodies with higher number of cones and also few to numerous satellites is seen. The latter may be in one or two regular circles or may be irregularly disposed. Silica bodies are absent in culms of *C. compressus, C. exaltatus, C. hyalinus* and *C. iria*. In other speciies the satellites are relatively few or even absent. Silica bodies other than cones are rare and are recorded in *C. platystylis* wherein guard cells enclose an irregular body (Fig. 2: I).

Eleocharis R.Br.

Silica bodies are recorded in all the three species studied. Usually 3-8 (-15) cones with few to many, small to large satellites are observed in *E. acutangula* and *E. geniculata*. *E. atropurpurea* is rather separable from the above in bearing up to 16 cones intermixed with several small cones in cells of the abaxial epidermis of sheath and culm. Besides, the glume (abaxial side) in this species shows silica cones in epidermal cells. Silica grain deposition was also observed in the wall sinuations of epidermal cells in *E.geniculata* as is also seen in *Fimbristylis complanata* (Fig.2: K).

Fimbristylis Vahl

Silica bodies are observed in all the organs of all the nine species studied except on sheath (adaxial side) (all spp.) and culm (*F. tenera*). Usually 1-5 cones are present in each cell. Besides satellites, few to numerous, widely spaced and large crescent-shaped projections are present around cones (Fig. 1: I,J). These are sometimes placed spirally or in two concentric rings or in an ellipse. Sometimes the cones tend to be nodular (*F. ovata*). There occur two-peaked cones (Fig. 1: M,N) (*F. bisumbellata*), flat- tipped cones (Fig. 1: L) (*F. complanata, F. miliacea*). At times numerous large bodies fill the cells. In *F. complanata*, large, prominent

---

Explanation to Fig. 2. A. Cones in two linear rows; B. Cones of unequal size placed obliquely in a cell; C. Cones of different sizes filling the cell; D. Particulate silica filling the cell; E. Spherical, echinulate silica body on the anticlinal wall; F. *Scleria rugosa* - Hemispherical, echinulate silica bodies in a pair on leaf adaxial surface; G. *Rhynchospora longisetis* – Hemispherical, echinulate silica bodies as in F; but bodies 3; H. *Rhynchospora longisetis* - Polar subsidiary cell with particulate silica and stoma enclosing an irregular silica body; I. Angular silica body enclosed in the stoma; J. *R. longisetis* - Square-shaped silica bodies in short epidermal cells on culms; K. *Fimbristylis complanata* - Epidermal cells on leaf abaxial surface bearing silica grains in wall sinuosities; L. *Fuirena ciliaris* - Silica deposition in the walls of epidermal cells on leaf abaxial surface. (All drawings are diagrammatic except F, H, I & K).

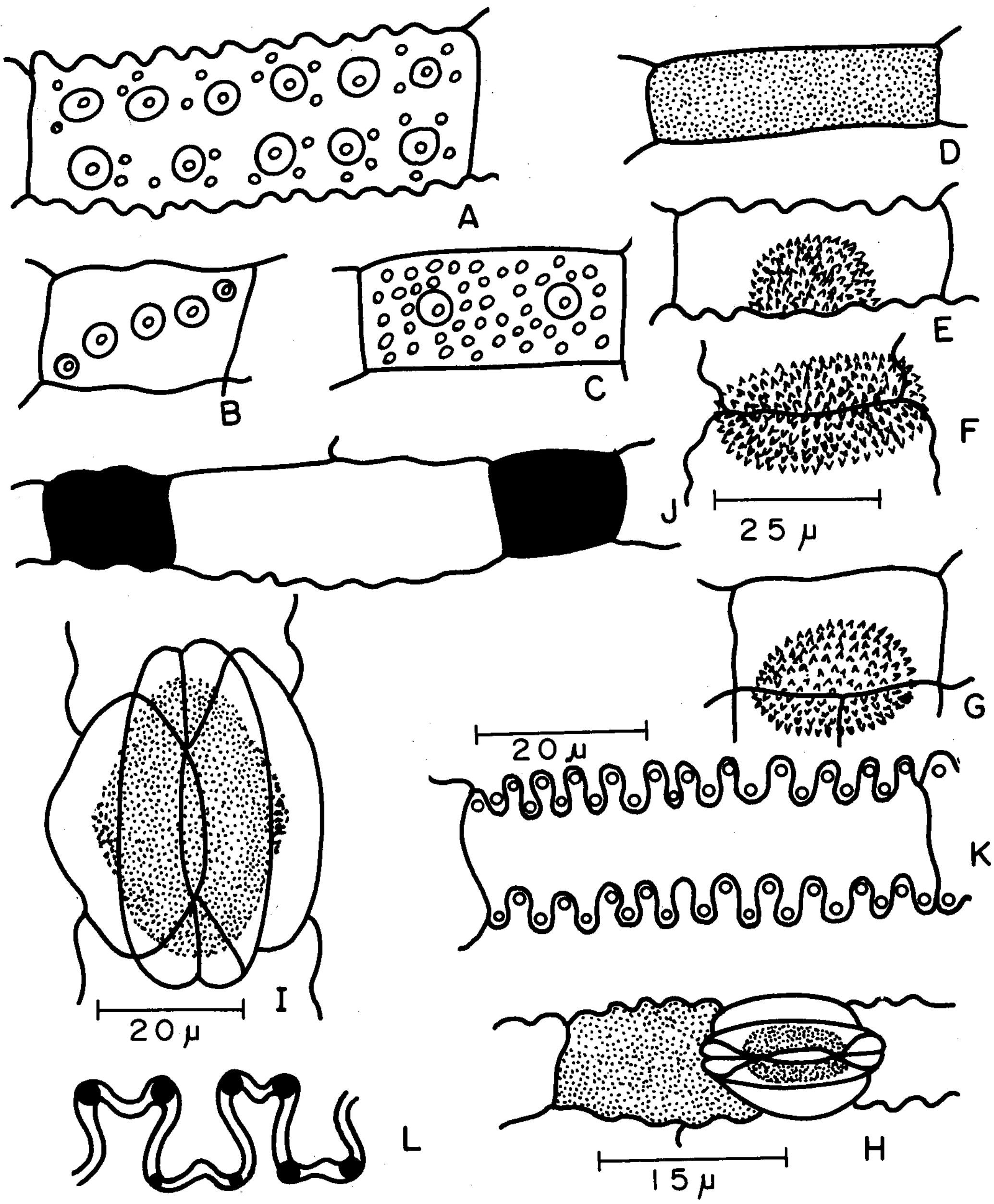


Fig. 2. Distribution of silica bodies in sedges

silica grains, ensheathed by a ring of cellular material are found in the wall sinuosities of epidermal cells of leaf, bract and culm (Fig. 2: K). Slight to negligible amount of deposition is also seen in other species.

Fuirena Rottb.

Usually 1-3 cones (including two-peaked ones), without satellites are observed. Silica deposition is also evident in the sinuosities of longer walls of epidermal cells in all organs (Fig. 2: L).

Kyllinga Rottb.

Here 2-6 silica cones surrounded by few to many satellites are recorded on leaf, bract and sheath. The culms in *K. brevifolia* are devoid of bodies while in *K. tenuifolia* the satellites are minute, being visible only in high magnifications.

Lipocarpha R.Br.

In the species studied, 2-5 cones with few to many rather irregular satellites are observed on leaf, bract and sheath. Culms show poor development of bodies with few silica cells and obscure satellites.

Mariscus Vahl

In the two species studied, 2-6 cones with numerous satellites are recorded in leaf and bract. In the case of *M.squarrosus*, the cones are present in two linear rows (Fig. 2: A), while cones are absent in culms of *M. clarkei*. Glumes show no satellites.

Pycreus Beauv.

The cones and satellites are well developed in most cases. Usually 2-10 cones surrounded by numerous to very numerous satellites (sometimes asymmetric) are seen. Cones are in 2 rows on leaf adaxial surface in *P. puncticulatus*, absent on sheath adaxial surface, glume adaxial of all species, absent on culms of *P. nilagiricus*, *P. pumilus* and *P. puncticulatus*.

Rhynchospora Vahl

R. longisetis is studied for the first time. Usually 1-4 (6) cone-shaped silica bodies with or without satellites are observed. In addition to the above, several interesting types of atypical bodies are recorded here. They are i) Hemispherical, warty or echinulate bodies in pairs (simialr to *Scleria*: Fig. 2: F) or in threes occurring in the adjoining intercostal cells (Fig. 2: G), ii) Particulate silica filling some costal and intercostal cells (Fig. 2: D), iii) Nodular bodies (cones with many peaks) in costal cells (Fig. 1: O), iv) Irregular silica body enclosed in guard cells (Fig. 2: H). All the above are found on leaf abaxial surface. Another type in the form of squarish silica body is found in short intercostal cells of culms (Fig. 2: J) (See also Discussion - atypical bodies).

Scirpus L. *s.l.*

Cone-shaped bodies are found in all species. Usually 3-5, but up to 11 cones in some, are recorded. There is much variation in satellites. They are often many, but may be conspicuous or small, or minute. In *S. juncoides*, there occurs numerous minute bodies placed far away from the main cone (Fig. 1: K). Possibly all these represent minute cones independent of the main cone. Some crescent-shaped projections are seen in *S. squarrosus*. Silica deposition of wall sinuosities of epidermal cells and around stomatal pore is also found in *S. articulatus*, *S. lateriflorus* and *S. juncoides*.

Scleria Berg.

In the two species studied for the first time, 2-5 cones (including flat-tipped cones) with usually several satellites are observed. In addition, atypical bodies like spherical (Fig. 2: E) and hemispherical echinulate bodies in pairs (Fig. 2: F) are found in intercostal cells of *S. rugosa*. Sand-like silica deposition is also noted in wall sinuations in some cases.

DISCUSSION

Silica bodies occur on all vegetative organs and also glumes, but are absent on bristles, scales, stamens and gynoecium. Besides the typical cone type, other types of silica bodies termed 'atypical' are also found in various taxa. The conical type of silica bodies are usually seen in costal cells and only in few cases (on glumes) they are developed in epidermal cells (inter-costal) as well. Generally speaking, each costal cell is a potential silica cell of both the surfaces of an organ, but cones are more frequent on abaxial surfaces of leaf, sheath, and bracts where they appear in continuous or discontinuous rows, the number of rows being equal to or less than the rows of costal cells. The adaxial surfaces of vegetative organs are generally devoid of silica bodies, especially where costal cells are not differentiated. In culms of several species, a low frequency of silica bodies are observed or they may be absent (e.g., in *Bulbostylis barbata*, *Cyperus* spp., *Kyllinga brevifolia*, and *Pycreus* spp.)

Cones may be small or large, the size sometimes varies within the same plant or even within the same organ. Occasionally, cones of variable size may be found within a single cell as in *Lipocarpha gracilis*. The number of cones range often from 1-10 per cell, and mostly the range is constant for a given surface or even a taxon. The cones are arranged in one or two (3) linear rows (Fig. 2: A) or sometimes obliquely (Fig. 2: B), or several cones filling the cell (Fig. 2: C). Sometimes the cones are with two peaks (Fig. 1: M) or with many peaks (Fig. 1: O,P) in which case they are described as nodular bodies. The cones may be simple without satellites around them or may be surrounded by satellites (the minor cones developing from the base of main cone), the former condition being more frequent on culms and glumes. Satellites may be very small and obscure or large and conspicuous, few to many and symmetrically (Fig. 1: E) or asymmetrically (Fig. 1: G,H) arranged around central cones. Sometimes, as in the case of *Scripus* spp., very small silica particles are observed in the place of satellites (Fig. 1: K). In some cases (*Fimbristylis* spp.) the cones bear projections on their shoulders which appear as crescent-shaped bodies in surface view (Fig. 1: I,J). The above characters, to a limited extent, can be of diagnostic value at species level and their value is enhanced when used in conjunction with other epidermal characters.

Ontogeny

The ontogenic studies of the cones in the epidermal cells of *Eriophorum comosum* by Mehra and Sharma (1965) revealed that it is a 'hat-shaped' body laid on a cone-shaped organic base of lignin which in turn is deposited on a thick non-lignified pad of the inner tangential wall of costal cells. Le Cohu (1973) has also shown that the cones of variable number are developed on a common base in each costal cell. But further studies are needed to explain the

Table 1. The species of sedges of Warangal and the form and organographic distribution of silica bodies

S. No.	Species Name [Acc. No.]	Leaf – abaxial epidermis	Leaf – adaxial epidermis	Sheath – abaxial epidermis	Sheath – adaxial epidermis	Culm	Bract	Glume – abaxial epidermis	Glume – adaxial epidermis	Stamen	Gynoecium
1	2	3	4	5	6	7	8	9	10	11	12
1	*Bulbostylis barbata* (Rottb.) Clarke [204]	C-2-4, S-6-10, Cons. at times Cs	+	C-3-7, S-5-8	A	A	++	+	A	A	A
2	*Cyperus alopecuroides* Rottb. [763]	C-2-5, S-α, Ir	+, but C-2-4	--	--	+, but C-3-4	++	+, but S-f	A	A	A
3	*C. articulatus* L. [762]	reduced to sheath with short blade	reduced to sheath with short blade	C-3-4	A	C-2-4, S-f	+++, S-larger A in adaxial	C-3-5, S-f	A	A	A
4	*C. bulbosus* Vahl [828]	C-3-6, S-very small	+, but C-2-3	+	A	C-2-4, S-often nil or OS	++	C with OS	As on Gl-ab	A	A
5	*C. castaneus* Willd. [477]	C-2-4, S-f. Cons.	+	C-3-5, S-f to α Cons.	A	C-2-4, S-f or OS	++	+, but C-up to 6	A	A	A
6	*C. cephalotes* Vahl [876]	C-3-6(7), S-α & Cons.	A	+	A	+, but C broader at base, S-fine	++	C-smaller, OS	A	A	A
7	*C. compressus* L. [287]	C-2-4, S-α, Ir	+	+	A	A	++	As above	A	A	A

1	2	3	4	5	6	7	8	9	10	11	12
8	*Cyperus difformis* L. [228]	C-2-5	+	+, but S-f	A	C-2-3, S-Inc.	++, but C- of 2 sizes	+, but OS	A	A	A
9	*C. exaltatus* Retz. [657]	C-2-4, S-8-12. Cons.	+	As above	A	A	++	+	A	A	A
10	*C. hyalinus* Vahl [1064]	C-4-10, S-f. Cons.	A	+	A	A	++	+, but OS	A	A	A
11	*C. iria* L. [227]	C-2-6, S-Cons.	+, but S-less clear	+, but S-f. or A	A	A	++	C-2-3, OS	A	A	A
12	*C. laevigatus* L. [310]	C-2-5, S-10-15	+, but S-f, Inc.	+	A	+	++	+	A	A	A
13	*C. meeboldii* Kuek. [250]	C-1-3, S-f. or A	+	-	-	C-1-3, WS.	++	C-1-2, WS.	As on Gl.ab.	A	A
14	*C. platystylis* R.Br. [1216]	C-1-3, S-α in a wide circle	A	C-3-6, S-+	A	C-infrequent, 1-3, S-A	-	+	A	A	A
15	*C. pulchellus* R.Br. [240]	C-2-4, S-α, Cons., Ir.	+	+, but C-1-3	A	C-2-4, S-A	++	+, but S-f	A	A	A
16	*C. rotundus* L. [233]	C-2-4. S-f to α	+	+	A	+, but S-f. or A	++	+	A	A	A
17	*C. rubicundus* Vahl [286]	C-(3)6-7. S-f. or α, Cons.	A	+	A	C-2-6, S-f.	++	+, but S-f or A	A	A	A

1	2	3	4	5	6	7	8	9	10	11	12
18	*Cyperus tenuispica* Steud. [211]	C-4-6, S-α, Cons. & Ir	-	-	-	C-3-7	++	C-obscure	A	A	A
19	*Eleocharis acutangula* (Roxb.) Schult. [126]	Leaf absent	Leaf absent	C-3-6, S-f. to α	A	+++	-	+++	A	A	A
20	*E. atropurpurea* (Retz.) Presl [524]	-do-	-do-	C-10-16(20), S-f. to α, large	A	+++	-	As in Culm, but C-7 in all cells	A	A	A
21	*E. geniculata* (L.) Roem. & Schult. [231]	-do-	-do-	C-4-8(15), S-f.	A	C-4-9, S-f., large	-	As in culm, OS	A	A	A
22	*Fimbristylis bisumbellata* (Forsk.) Bub. [700]	C,2P-3(5), S-f., large, inner Cs	+	+, but 2P. frequent	A	+ but S-f to α, often Cs	++	+, but Cs-f	A	A	A
23	*F. complanata* (Retz.) Link [235]	As above but S-f. to α	+, C-flat tipped, S-α	+, but C-flat tipped, S-α.	A	+	++	+	A	A	A
24	*F. ferruginea* (L.) Vahl [222]	C-1-2, Cs present	+	+, but Cs α	A	+, with 2-8 small cones around C	++	Silica all over, C-variable S-normal or Cs	A	A	A

1	2	3	4	5	6	7	8	9	10	11	12
25	*Fimbristylis miliacea* (L.) Vahl [217]	C-2-5, unequal, S-α, cones	+	+, but few C, flat-tipped	A	+	++	+, but C-smaller	A	A	A
26	*F. ovata* (Burm.f.) Kern [321]	C-1-3, S-f. Cons., some C-nodular	+	+, but C-1-3, S-f. to α	A	+, C-2-3	organ glume-like	+, but project-ions	A	A	A
27	*F. quinquangularis* Kunth [809]	C-2-4, Cs Presnet	+	C-2-3, S-α, well spaced	A	+++	++	+	A	A	A
28	*F. schoenoides* (Retz.) Vahl [480]	C-2-4, inner S, Cs	+	+	A	C-2-5, S-f., widely spaced	Bract small	-	A	A	A
29	*F. tenera* Schult. [903]	C-2-5, S-f., Inner Cs	+	+	A	Culm slender	Bract small	-	A	A	A
30	*F. tetragona* R.Br. [756]	Leaf reduced to sheath	Leaf reduced to sheath	C-3-6, S-f., large inner Cs	A	C-2-3	Bract absent	+++	A	A	A
31	*Fuirena ciliaris* (L.) Roxb. [498]	C-1-3(5), some 2P, S-A	+	+	A	+, but less frequent	++	+	As in Gl. ab	A	A
32	*Kyllinga brevifolia* Rottb. [475]	C-3-6, S-f. to α, Cons.	+	+	A	A	+, C-2-3	As on bract	A	A	A

1	2	3	4	5	6	7	8	9	10	11	12
33	*Kyllinga tenuifolia* Steud. [239]	C-2-4, S-α, Cons.	C-2-3, S-f. to α, Ir	C-2-4, S-Cons.	A	C-3-5, S-fine	++	As on culm	A	A	A
34	*Lipocarpha gracilis* (Pers.) Nees [485]	C-2-5, unequal, S-f. to α, Ir or oblique	+	+	A	C-2-4, S-minute or Os	++	+	A	A	A
35	*Mariscus clarkei* T. Cooke [246]	C-2-3, S-α	+	+	A	A	++	C-2-3, WS	A	A	A
36	*M. squarrosus* (L.) Clarke [839]	C-3-8, S-25	+	C-4-7, in 2 rows,S-Inc.	+++	+, S-23, Ir	++	C-5	A	A	A
37	*Pycreus diaphanus* (Roem. *et* Schult.) Hooper & Koyama [757]	C-6-10, S-α	+	+	A	C-4	++	C-3-6, S-f.	A	A	A
38	*P. flavidus* (Retz.) Koyama [810]	C-2-5, S-α	+	C-2-6, S-α	A	+	++	+	A	A	A
39	*P. nilagiricus* (Steud.) Camus [751]	C-2-4, S-f-α, Ir	+, but S-f. large	+	A	A	++	C-1-3, S-f.	A	A	A

1	2	3	4	5	6	7	8	9	10	11	12
40	*Pycreus pumilus* (L.) Nees ex Clarke [476]	C-3-7, S-f.	+	-	-	A	++	C-f.	A	A	A
41	*P. puncticulatus* (Vahl) Nees [474]	C-3-7, S-10-12	C-3-6, in 2 rows, S-α	C-2-7, S-8-15	A	A	++	+, but S-Cons.	A	A	A
42	*P. sanguinolentus* (Vahl) Nees *ex* Clarke [208]	C-3-8, S-10-α, Cons.	C-2-5	+	A	+, but C-2-6	++	C-present	A	A	A
43	*Rhynchospora longisetis* R.Br. [460]	C-2-4, S-f., or A, EC, Nb, PS seen	CI-2	C.-4, S-Cons.	A	+ & Sqs.	++	C-6, OS	A	A	A
44	*Scirpus articulatus* L. [643]	Leaf reduced to sheath	Leaf reduced to sheath	C-2-3, S-smaller	A	C-2-4	-	C-1-3	A	A	A
45	*S. jacobii* Fischer [569]	-do-	-do-	C-2-3, S-f., Cons.	A	C-2-5(7), S.f. to α	-	As in culm	A	A	A
46	*S. juncoides* Roxb. [43]	-do-	-do-	C-1-2, S-α, minute, away from C	A	+++	-	+++, but C-1-3	A	A	A
47	*S. lateriflorus* J.F. Gmelin [210]	C-2-11, S-α, small crowded	+, but C-2-3 (6)	+, C-2-5	A	C-1-2(3),S-f., Inc.	++	+	A	A	A

1	2	3	4	5	6	7	8	9	10	11	12
48	*Scirpus maritimus* L. [654]	C-1-4, S-α, Cons., Ir	+	C-3-5, S-small or obscure	A	+	++	Silica all over, C-unequal, S-f. to α	A	A	A
49	*S. squarrosus* L. [220]	C-2-3, S-f. to α. Cons., inner with projections	+	C-9, +	A	C- 5	++	-	-	-	-
50	*Scleria biflora* Roxb. [1125]	C-2-4, S-α, small, Cons.	C-1-2	+	A	C-3-4,flat tipped, S. small	-	C with S-α	A	A	A
51	*S. rugosa* R.Br. [464]	C-3-5, S-α	+, Also EC	C-2-4, S-f.	A	C-2-4, S-α, large	++	C with S, small or OS	A	A	A

Abbreviations used in the Table:

A = Absent; C = Central cones per cell; Cons = Conspicuous; Cs = Satellites in the form of crescent-shaped projections; EC = Echinulate bodies; f = few; Inc = Inconspicuous; Ir = Irregular or asymmetrically arranged around cone; Nb = Nodular bodies; OS = Obscure satellites; PS = Particulate silica; S = Satellite; 2P = Two peaked cones; Sh = Sheath; Sqs = Square shaped silica bodies; WS = Without satellites; + = As in leaf abaxial; ++ = As in leaf abaxial, adaxial respectively; +++ = As in sheath abaxial; α = numerous; Gl = Glume; ab = abaxial.

development of satellites, minute cones, crescent-shaped projections (as in *Bulbostylis, Fimbristylis*, and *Fuirena*), and nodular bodies.

In addition to the above considerations, a point which is emphasised (Metcalfe, 1960; Mehra & Sharma, 1965) is that the silica cells bearing silica cones are so distinctive in their structure and so precise in their location that they need be designated as "cyperaceous type" and this type has not been reported to occur outside Cyperaceae. Further, the silica cells of Cyperaceae are distinctly different from those of Gramineae (Metcalfe, 1960), a family which until recently has been thought to be phylogenetically closely related to the Cyperaceae (Hutchinson, 1973). The silica bodies of these two families are shown to be distinguishable from each other as given below.

In Cyperaceae, the silica cells as a rule occur in costal cells which are all alike and are potential silica cells bearing cone-shaped silica bodies though cones may not develop in all cells. The cones as noted earlier may range form one to many and have the characteristic structure and ontogeny. While in Gramineae, the epidermis is highly specialised and silica cells occur in both costal and inter-costal cells and are in the form of short cells, either solitary, paired with cork cells or alternate with cork cells in rows of three to more than five. Atypical bodies found in intercostal cells and confined to few taxa of Cyperaceae are also distinct form those of grasses. Further, no information is available on the ontogeny of silica bodies and only a single silica body of variable shape occurs per cell.

A perusal of literature also reveals a number of instances where the account given for a species with regard to the number of silica cones per cell and the presence or absence of satellites and their number, differs from author to author. However, it is known that younger parts of a plant generally lack satellites, while the latter are developed in mature parts. Gordon-Gray (1971) is of the opinion that the variation associated with the extent of development of satellites may be environmental, though he has not done any experimental work on this aspect. Working on the morphology and anatomy of several Sough African species of *Bulbostylis* and *Fimbristylis* so as to understand their generic limits, he concluded that *Fimbristylis* spp. are moisture-loving and live in an environment where a reasonable level of silicon is present for uptake and hence bear more silica bodies, while species of *Bulbostylis* showing greater tolerance of drier habitats, bear less number of bodies. In the present study, always mature parts of the organs were studied and the data indicated that there exists a basic pattern for each taxon as far as the main type of silica deposition is concerned. But experimental studies may be needed to assess the role of environment in the development of accessory bodies such as satellites, projections, etc.

'Atypical' silica depositions

In contrast to the conventional types of cone-shaped silica bodies either with or without satellites, other types of silica depositions in different interesting forms, considered as atypical, are recorded in some cyperaceous taxa. Because of their restricted occurrence, these are taxonomically more useful than the cone-shaped bodies. These are invariably found in inter-costal cells and stomatal guard cells. Rarely the atypical bodies occur in costal cells especially the silica particles (Fig. 2: D). Reports on the occurrence of these deposits are found sporadically in literature, though there are studies exclusively devoted for these types (Govindarajalu, 1969c). Metcalfe (1971) gives an account of these types. These are warty, wedge-shaped, bridge-shaped, fine particulate bodies which fill the lumina of the cell, and conglomerates which are spherical, hemispherical or fusiform in shape while their surfaces may be smooth, warty or echinulate. In addition, many other types have been described in *Rhynchospora* spp. (Govindarajalu, l.c).

Some of the atypical silica bodies found in the sedges studied here are i) Sand-like or ill-defined silica depositions noticed in the sinuosities of anticlinal walls of epidermal cells, ii) Particulate silica filling the epidermal cells, iii) Hemispherical, dome-shaped or spherical bodies with smooth, warty or echinulate surfaces which may be in pairs or threes lying against the anticlinal walls of adjacent epidermal cells, iv) Squarish, smooth silica bodies occurring in some short epidermal cells (Fig. 2: J), and v) Irregular or angled silica bodies enclosed in stomata (Fig. 2: I). Silicification of walls to varying degrees is also noticed in respect of epidermal cells, costal cells, guard cells and trichomes.

A perusal of the data on silica bodies (c.f. Table 1) indicate that they are taxonomically very important at various levels. In certain genera, the variation in the silica bodies among the species can be utilised to diagnose them. In the genus *Cyperus*, presence of an irregular silica body in guard cells of *C. platystylis* clearly separates the latter from other species. The variations in the number of cones per cell, their distribution, the number and arrangement of satellites are also useful to diagnose other species of this genus. In *Eleocharis*, the species *E. atropurpurea* is separable from the other two taxa in having higher number of cones intermixed with several smaller cones per cell. The silica bodies have limited diagnostic value in the genus *Fimbristylis* as we find a stable pattern throughout. *F. ovata* differs from others in bearing nodular bodies. In *F. complanata*, the presence of large, prominent silica grains, ensheathed by a ring of cellular material, in wall sinuosities of epidermal cells is a noteworthy feature.

The variation in the number of cones and their distribution is also found useful in other genera like *Kyllinga, Mariscus* and *Pycreus*. Further, it is noted that the pattern in *Kyllinga* and *Pycreus* is not much different from that of *Cyperus s.s.* while that of *Mariscus* agrees with it.

In the genus *Scirpus, S. juncoides* is distinctive on account of numerous small silica particles, placed far away around main cone. Possibly these particles represent minute cones as they tend to become broader when the focus is lowered under the lens. Earlier, Govindarajaju (1976) stated that satellites are absent in this case, probably as they lie far away from the main cone.

TAXONOMIC CONSIDERATIONS AND CONCLUSIONS

A critical study of the silica bodies in the present work enable us to make comments on the taxonomic treatment of some genera.

Cyperus L.

There are two divergent views on the systematic treatment of the genus *Cyperus*. Clarke (1893) divided *Cyperus* into 7 genera on the basis of number of stigmas, achene position and glumes in a spikelet. Kern (1974) disagreed and termed the above as artificial as the genera are ill-defined and preferred to give them subgeneric rank. Koyama (1961) treated *Cyperus* in a wide sense (including *Lipocarpha*) as all the taxa possess cyperus-like embryo. Similar are also the views of van der Veken (1965), who found uniform embryo type in all the 132 species of *Cyperus* studied by him. Daniel and Sabnis (1978) on the support of their chemical data (14 spp. only) also agreed with the above views. Metcalfe (1971) and many others provided ample anatomical evidence to indicate a close affinity between *Cyperus* and other genera like *Kyllinga, Mariscus, Pycreus*, etc. Metcalfe (l.c.) found some features by which some genera can be separated from *Cyperus*, viz. *Kyllinga, Mariscus* and *Pycreus*, and preferred to study more species before making any definite conclusions. Govindarajalu (1969-78) felt that latter genera have more similarities to *Cyperus* than differences and was in favour of giving subgeneric rank. But in the studies by Haines and Lye (1971) the authors gave importance to morphological differences seen from a phylogenetic view point and preferred to spilt *Cyperus* into many genera. This course appears to be more reasonable in the absence of adequate chemical and cytological data from larger number of species. The present evidence on silica bodies and other epidermal features (Satyanarayana Reddy, 1985) do not provide any clear indications on this issue as the pattern in different genera is either similar to that of *Cyperus s.s.* or is not much differcnt from the latter.

Lipocarpha R. Br.

Divergent opinions exist on the question of affinity of this genus with the tribes Scirpeae or Cypereae, based on the varying interpretations of the nature of scales in the floral unit. *Lipocarpha* is even sunk in *Cyperus* as the former is said to possess a similar embryo type. But pollen studies led Makde (1983) to disagree with the above view. There is also an opinion (Koyama, 1982) favouring recognition of a separate tribe *Lipocarpheae* to accommodate *Lipocarpha* and few other allied genera. The evidences so far on silica bodies indicate that *Lipocarpha*, at least, is not closer to *Scirpeae* than *Cypereae*.

Fimbristylis Vahl

As stated earlier, a constant feature in the species studied here is the presence of few to many crescent-shaped silica projections around cones and also deposition of silica material in wall sinuosities. It is significant that these features are also associated with *Bulbostylis* and *Fuirena* which along with *Fimbristylis* belong to the same tribe Scirpeae, thus indicating close affinity. Further, the question of generic limits between *Bulbostylis* and *Fimbristylis* remains open. The separate status of the former is justified on morphological, embryological and chemical grounds (Clarke, 1902; Kern, 1974; Hooper, 1976). Those who like to merge these genera emphasise the similarity in cytological and anatomical aspects (Koyama, 1961; Metcalfe, 1971). Though silica bodies of *B. barbata* and *Fimbristylis* spp. are similar, the trichomes of the former are distinct (Satyanarayana Reddy, 1985).

Eleocharis R. Br.

The genus *Eleocharis* is considered natural and homogeneous, though opinions may vary on its closeness to other genera. Here the tendency to develop higher number of cones in a cell is a unifying character.

Scirpus L.

The genus *Scirpus* is sometimes split on account of its heterogeneous nature owing to morphological and anatomical variations (Van der Veken, 1965; Metcalfe, 1971; Palla, 1888). But in the opinion of Kern (1974), splitting of the genus will result in taxa which are heterogeneous and consist of dissimilar species. Further work, including chemical, on more species is favoured before any reliable assessment of inter-relationships within the genus can be made. The information from surface-view studies of the epidermis also needs to be collected from more species to make any logical conclusions.

Rhynchospora Vahl

The restricted occurrence of 'atypical' silica bodies being confined to few genera, enhances their taxonomic value. *Rhynchospora* is one of the genera in which the atypical bodies are commonly encountered (see under Observations). Many types of these bodies including those recorded here are reported in the earlier studies (Metcalfe, 1971; Govindarajalu, 1969c). Metcalfe (l.c) commented that the occurrence of atypical bodies in this genus is unusual, for these are characteristic of the tribe Scleriae and are absent in Cypereae with few exceptions.

Scleria Berg.

The present data on atypical bodies in this genus is in conformity with the earlier studies (Metcalfe, 1971; Govindarajalu, 1975). The presence of atypical bodies were regarded as most remarkable feature which serves to distinguish *Scleria* from most other genera of Cyperaceae.

In conclusion it may be said that data on silica bodies when coupled with that of other epidermal features like stomata and trichomes form a potential tool in taxonomic conclusions and also in constructing keys to taxa. The same will be presented in later publications of this series.

Acknowledgements

The authors are grateful to the Head, Deptartment of Botany, Osmania University, Hyderabad for providing facilities. One of the authors (PSR) is much grateful to the University Grants Commission for the award of Teacher Fellowship which enabled him to carry out the work.

Literature cited

Ahuja, A. 1962. Studies on the epidermis of some members of Cyperaceae. *Curr. Sci.* 31: 213-14.

Clarke, C.B. 1893. Cyperaceae. *In*: J.D. Hooker, *Fl. British India* 6: 585-672.

Clarke, C.B. 1902. Cyperaceae. *In*: Thiselton-Dyer, *Flora of Tropical Africa* 8: 411-446.

Daniel, M. & S. D. Sabnis. 1978. Chromatographic profiles in the classification and identification of the Cyperaceae. *J. M.S. Univ. Baroda* 15 & 16(3):19-26.

Duval-Jouve, J. 1873. Sur une forme de cellules epidermiques qui paraissent propres aux cyperacees. *Bull. Soc. Bot. Fr.* 20:91-5.

Gordon-Gray, K. D. 1971. *Fimbristylis* and *Bulbostylis*: Generic limits as seen by a student of Southern African Species. *Mitt. Bot. Staatssamml. Munchen* 10: 549-74.

Govindarajalu, E. 1966. The systematic anatomy of South Indian Cyperaceae: *Bulbostylis* Kunth. *J. Linn. Soc. (Bot.)* 59: 289-304.

Govindarajalu, E. 1969a. The systematic anatomy of South Indian Cyperaceae: *Fuirena* Rottb. *Bot. J. Linn. Soc.* 62: 27-40.

Govindarajalu, E. 1969b. The systematic anatomy of South Indian Cyperaceae: *Cyperus* L. subgen. *Kyllinga* (Rottb.) Suringar. *Bot. J. Linn. Soc.* 62:41-58.

Govindarajalu, E. 1969c. Observations on new kinds of silica deposits in *Rhynchospora* spp. *Proc. Indian Acad. Sci.* (B) 70: 28-36.

Govindarajalu, E. 1974. The systematic anatomy of South Indian Cyperaceae: *Cyperus* L. subgen. *Juncellus, Cyperus* subgen. *Mariscus*, and *Lipocarpha* R. Br. *Bot. J. Linn. Soc.* 68: 235-66.

Govindarajalu, E. 1975. The systematic anatomy of South Indian Cyperaceae: *Eleocharis* R.Br., *Rhynchospora* Vahl, and *Scleria* Berg. *Adansonia* Ser. 2, 14: 581-632.

Govindarajalu, E. 1976. The systematic anatomy of South Indian Cyperaceae: *Scirpus* L. *s. lat. Adansonia.* Ser. 2, 16: 13-38.

Govindarajalu, E. 1978. The systematic anatomy of South Indian Cyperaceae: *Cyperus* L. subgen. *Pycreus* (P. Beauv.) C.B.Cl. *Adansonia* Ser. 2(1), 18: 95-128.

Govindarajalu, E. 1981. The systematic anatomy of South Indian Cyperaceae - Novelty in *Lipocarpha: L. raynaleana* and its vegetative anatomy. *Adansonia* Ser. 2, 20: 369-75.

Haines, R. W. & K. A. Lye. 1971. Studies in African Cyperaceae - 4. *Lipocarpha* R.Br., *Hemicarpha* Nees, and *Isolepis* R. Br. *Botaniska Notiser* 124: 473-82.

Hooper, S. S. 1976. Cyperaceae. *In*: C.J. Saldanha & D.H. Nicolson. *Flora of Hassan District, Karnataka, India.* Amerind Publishers, New Delhi. pp.655-701.

Hutchinson, J. 1973. *Families of flowering plants.* Oxford.

Kern, J. H. 1974. Cyperaceae. *In:* C.G.G.J. Van Steenis (Ed.), *Flora Malesiana* Ser. I, 7(3): 435-753.

Koyama, T. 1961. Classification of the family Cyperaceae. *I. J. Fac. Sci., Univ. Tokyo,* Sect. 3, Bot. 8: 37-148.

Koyama, T. 1982. The genus *Lipocarpha* R.Br., it's morphology and systematic position in the family Cyperaceae. *Actaphytotox. Geobot.* 33(0): 218-26.

Le Cohu, M. C. 1973. Examen au microscope electronique a balayage des cones de silica chez les cyperacees. *C. R. Acad. Sci. Paris,* D.277:1301-1303.

Lee, Y. N. & Y. C. Oh. 1971. A study of epidermal patterns of the leaf blades of Korean sedges (2). *J. Korean Inst. Better Living* 7: 41-54.

Makde, K. H. 1983. Embryology of *Lipocarpha* with a brief discussion on it's systematic position. *J. Ind. Bot. Soc.* 62: 36-42.

Mani, A. P. 1963. Leaf anatomy in the identification of *Cyperus* species. *Trans. Bose. Res. Inst.* 26: 119-128.

Mehra, P. N. & O. P. Sharma. 1965. Epidermal silica cells in the Cyperaceae. *Bot. Gaz.* 12(1): 53-58.

Mehra, P. N. & O. P. Sharma. 1969 (1970). Systematic anatomy of *Cyperus* L. *Res. Bull. Punjab Univ. Sci.* 20: 119-137.

Metcalfe, C. R. 1960. *Anatomy of the monocotyledons*. I. *Gramineae*. Oxford.

Metcalfe, C. R. 1964. Systematic anatomy of monocotyledons. *Notes Jodrell Lab.* 2: 1-8.

Metcalfe, C. R. 1969. Anatomy as an aid to classifying the Cyperaceae. *Amer. J. Bot.* 56: 782-90.

Metcalfe, C. R. 1971. *Anatomy of the monocotyledons*. V. *Cyperaceae*. Oxford.

Metcalfe, C. R. & M. Gregory. 1964. Some new descriptive terms for Cyperaceae with discussion of variations in leaf form noted in the family. *Notes Jodrell Lab.* 1: 1-11.

Oh, Y. C. 1974. A study of the epidermal patterns of the leaf blades on Korean sedges, *Eriopohorum, Fuirena, Kobresia, Rhynchospora* and *Scirpus*. *Korean J. Bot.* 17: 99-105.

Palla, E. 1888. Zur kenntnis der Gattung *Scirpus*. *Bot. Jahrb.* 10: 293-309.

Pfeiffer, H. 1921. Derheutige stand unserer kenntnisse von der Kezelzellen der Cyperaceen. *Ber. dt. Bot. Ges.* 39: 353-64.

Pfeiffer, H. 1927. Untersuchungen Zurvergleinchen-den Anatomic der Cyperaceen. I. Die anatomie der Blatter. *Beih. Bot. Zbl.* 44(1): 90-176.

Rajagopal, T. 1973. Flora of Hyderabad including a study of the foliar epidermal characters of the species as an aid to Taxonomy. Ph.D. Thesis, Osmania University, Hyderabad, India.

Rajagopal. T. & P. Satyanarayana Reddy. 1984. Taxonomical and anatomical observations on *Cyperus meeboldii* Kuek., a little known sedge from India. *Ind. J. Bot.* 7(1): 56-63.

Sharma, O. P. & P. N. Mehra. 1972. Systematic anatomy of *Fimbristylis* Vahl (Cyperaceae). *Bot. Gaz.* 133: 87-95.

Satyanarayana Reddy, P. 1985. Floristic study of Warangal and Epidermology of Cyperaceae as an aid to Taxonomy. Ph.D. Thesis, Osmaina University, Hyderabad, India.

Staudermann, W.Von. 1924. "Die Haare der Monokotylen". *Bot. Arch.* 8: 105-184.

Van der Veken, P. 1965. Contribution a l'embryographie systematique des Cyperaceae-Cyperoideae. *Bull. Jard. Bot. Etat. Bruxelles* 35: 285-352.

Vignal, C. 1970. Contribution a l'etude epidermique dequelques Cyperacees: *Carex, Cyperus, Scirpus* et *Kobresia*. *Ann. Fac. Sci. Marseille Biol. Veg.* 42: 313-21.