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Opaline Silica in the Leaves of Some Grasses and Sedges of Karachi

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Abstract: The deposits of silicon in the leaves of several grasses and sedges have been investigated. Shape and distribution patterns of opal phytoliths were examined in the adaxial surface of leaf blades. Dumb-bell shape was found to be most common, such phytoliths were generally arranged in two or three rows. Rod, sphere and saddle-shaped phytoliths were specific for certain species and this can be used as a diagnostic character to delimit such species.

Key words: Opaline, silica, grasses, sedges

Introduction

The plant opals are microscopic amorphous bodies which occur in living plants. The term "phytoliths" is used to describe plant opals having repetitive shapes. Phytoliths survive in sediments and soils and have therefore been used as indicators of paleosols, in archaeological reconstructions and as indicators of past vegetation. Classification of the opal was on a morphological basis since in soil materials such opal become fragmented and less reliably identified as being derived from a particular cell. They identified rods, spheres, etc. and in some cases related them to various cells within the plants, although not to a particular species. Assemblages of phytoliths in soils have also been used to assist in identification of the originating flora (Rovner, 1983).

The occurrence of silica deposits in plants has been investigated by many workers. Comprehensive studies have been conducted on *Zea mays* (Lanning *et al.*, 1980); on cereals (Bennett and Parry, 1980); on *Zea mays* (Bennett and Sangster, 1981); on higher plants (Kaufman *et al.*, 1981) and on *Miscanthus sacchariflorus* (Sangster, 1983). Metcalfe and Chalk (1983) investigated opaline silica in angiospermic trees and shrubs. Parry *et al.* (1985) reported the distribution of silicon deposits in the fronds of *Pteridium aquilinum*. Hart (1988) studied trees and shrubs of Australia and (Borre and Watson, 1994) investigated opaline silica in leaves of *Eragrostis*. Watson and Dallwitz (1993) used opaline silica for identification of grasses. Silica deposition in rice (*Oryza swivel* L.) has been extensively studied (Whang, 1993; Whang and Kim, 1994; Whang *et al.*, 1998).

The present study examines the occurrence, structure and distribution of phytoliths in the leaves of some grasses and sedges commonly found in Karachi, Pakistan.

Materials and Methods

Fifteen grass species and two sedge species were collected from different localities in Karachi. Voucher specimens have been deposited in Plant Ecology Laboratory at the Department of Botany, University of Karachi, Pakistan. The species studied are listed below: The technique used for making surface preparations was similar to that employed for the study of opaline silica in the leaves of grasses (Parry and Smithson, 1958, 1964). Leaves were washed with distilled water and small pieces were transferred onto the glass slides. A few drops of dilute chromic acid were added and the material left for about 15 minutes. The tissues were washed with distilled water and mounted in glycerine. The adaxial surfaces of leaves were examined under light microscope (x10, x40) and the shape and distribution of opaline phytoliths were observed. The length and breadth of opaline phytoliths were measured using ocular micrometer after calibration. Photographs were taken at x10 and x40 magnifications.

In order to assess the phonetic similarities among the taxa on the basis of phytolith characteristics and their distribution patterns, a cluster analysis was performed. Gower (1971) similarity coefficient was used as it has the ability to deal with mixed data types. Hierarchical agglomerative clustering was accomplished using average linkage clustering strategy (Everitt, 1980).

Results

The opaline silica bodies in the leaves of the 17 species studied (15 grasses and 2 sedges) exhibited considerable variation with respect to shape, distribution pattern, size, density and position on leaves (Table 1). In grass leaves some of the costal cell (long silica cells) and some of the intercostal cells (short silica cells) usually forming part of silico-suberose couples normally acquire silica at an early stage and in a regular manner. The bodies vary in form, straight-sided to lobed, with two to three lobes on each edge. The various shapes of opaline silica were observed, including dumb-bell shaped, rod-shaped square and saddle-shaped. Since the shape of phytolith is the most consistent and a diagnostic feature, further results are described in sequel with respect to shape.

The various shapes of the plant opal found are described in the sequel.

Dumb-bell shaped phytoliths: The adaxial leaves of some grasses showed well aligned bodies usually with two lobes on each edge forming the so called (dumb-bells) and also three lobes edges were seen. Dumb-bell shaped phytoliths were found in *Panicum turgidum* (Fig. 3a, b), *Eragrostis poaeoides* (Fig. 1e), *Sporobolus marginatus* (Fig. 3d), *Setaria verticillata* (Fig. 3e), *Cyperus bulbosus* (Fig. 2a, b), *Lasiurus hirsutus* (Fig. 1f), *Cynodon dactylon* (Fig. 1b) and *Aristide mutabllis* (Fig. 1a). Opal phytoliths were arranged in chains in *Panicum turgidum* (Fig. 3a, b), *Eragrostis poaeoides* (Fig. 1e), *Cyperus bulbosus* (Fig. 2a, b), *Lasiurus hirsutus* (Fig. 1f), *Cynodon dactylon* (Fig. 1b) and *Aristide mutabllis* (Fig. 1a) while in *Sporobolus marginatus* (Fig. 3d) and *Setaria verticillata* (Fig. 3e) dumb-bell shaped phytoliths were not arranged in chain. Three lobed phytoliths were found in *Dichanthium annulatum* (Fig. 2g, h), *Dactyloctenium aegyptium* (Fig. 1h) and *Cenchrus pennisetiformis* (Fig. 1d, Table 1).

Rod-shaped or Rectangular-shaped phytoliths: Rod-shaped phytoliths was found in only one species i.e. *Eragrostis pilosa* (Fig. 2d). They were distributed sparsely and had smooth surface (Table 1).

Sphere-shaped or Rounded phytoliths: *Cyperus rotundus* (Fig. 3c) showed only sphere or rounded phytoliths. They were arranged in one row. All the sphere were approximately of the

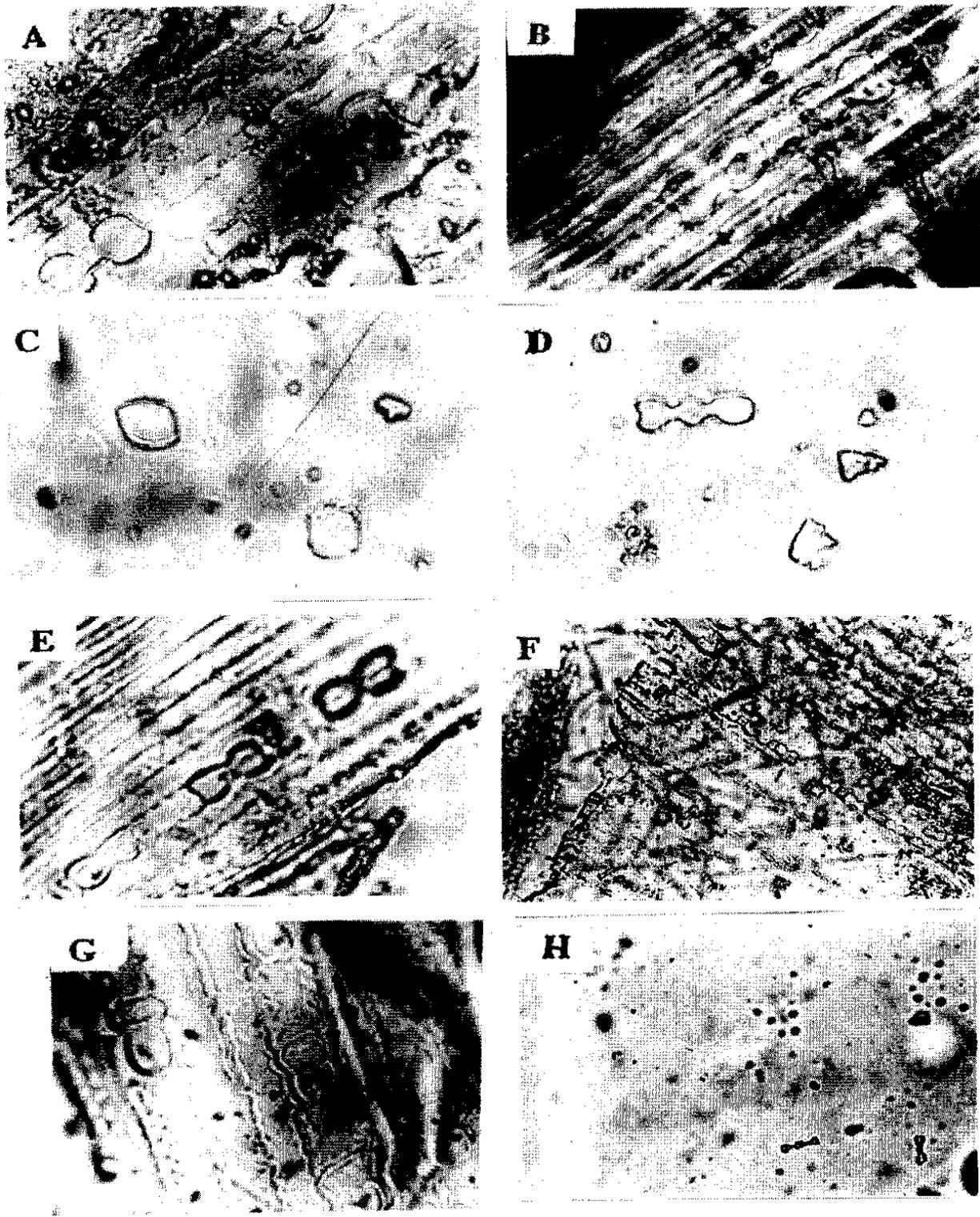


Fig. 1: Light micrographs showing opaline silica in the adaxial surface of leaves. A. *Aristida mutabilis* x600, B. *Cynodon dactylon* x600, C. *Chloris barbata* x600, D. *Cenchrus pennisetiformis* x600, E. *Eragrostis poaeoides* x600, F. *Lasiurus hirsutus* x150, G. *Saccharum munja* x600, H. *Dactyloctenium aegyptium* x150

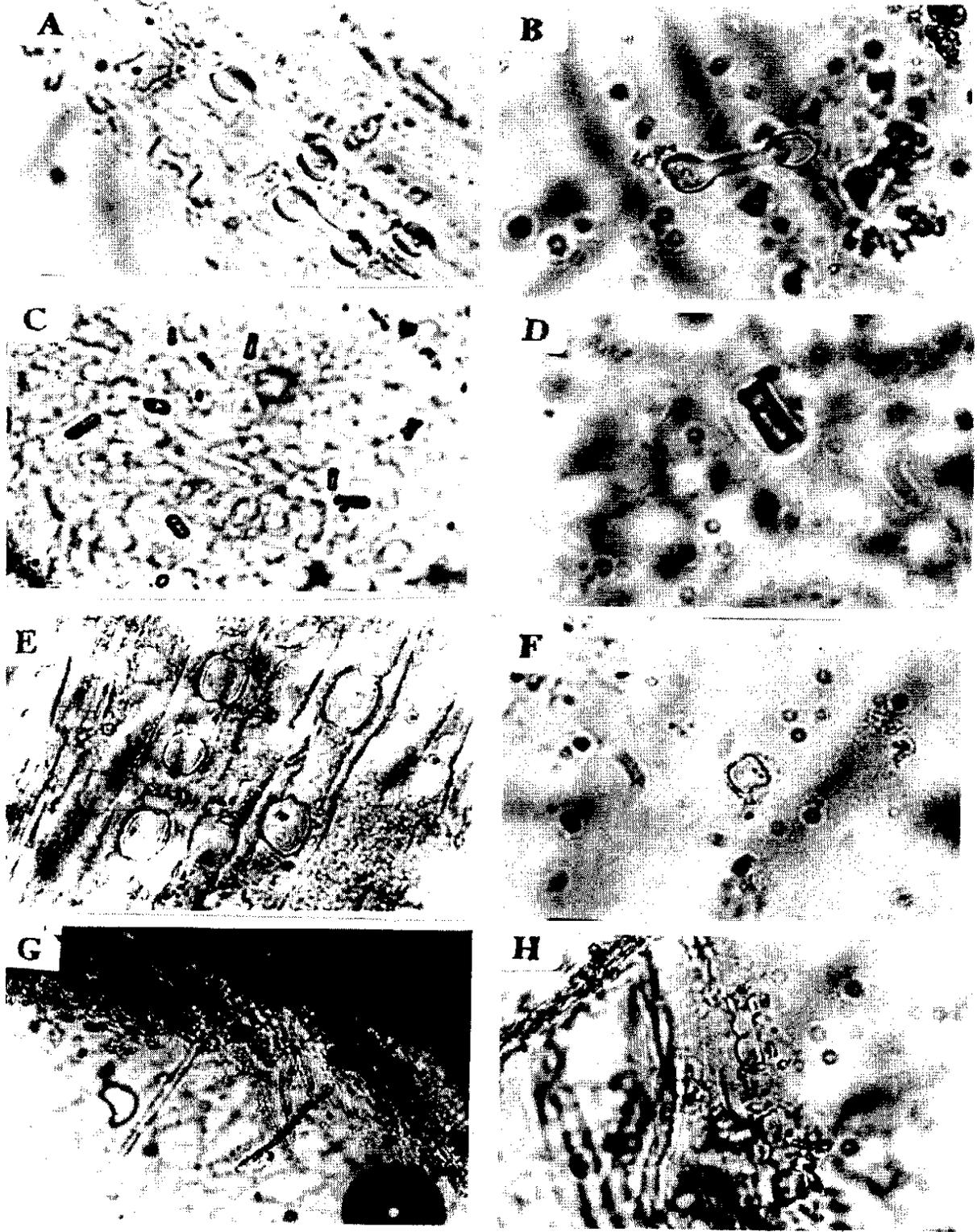


Fig. 2: Light micrographs showing opaline silica in adaxial surface of leaves. A. *Cyperus bulbosus* x600, B. *Cyperus bulbosus* x600, C. *Eragrostis pilosa* x150, D. *Eragrostis pilosa* x600, E. *Brachiaria ramosa* x600, F. *Brachiaria ramosa* x600, G. *Dichanthium annulatum* x150, H. *Dichanthium annulatum* x600

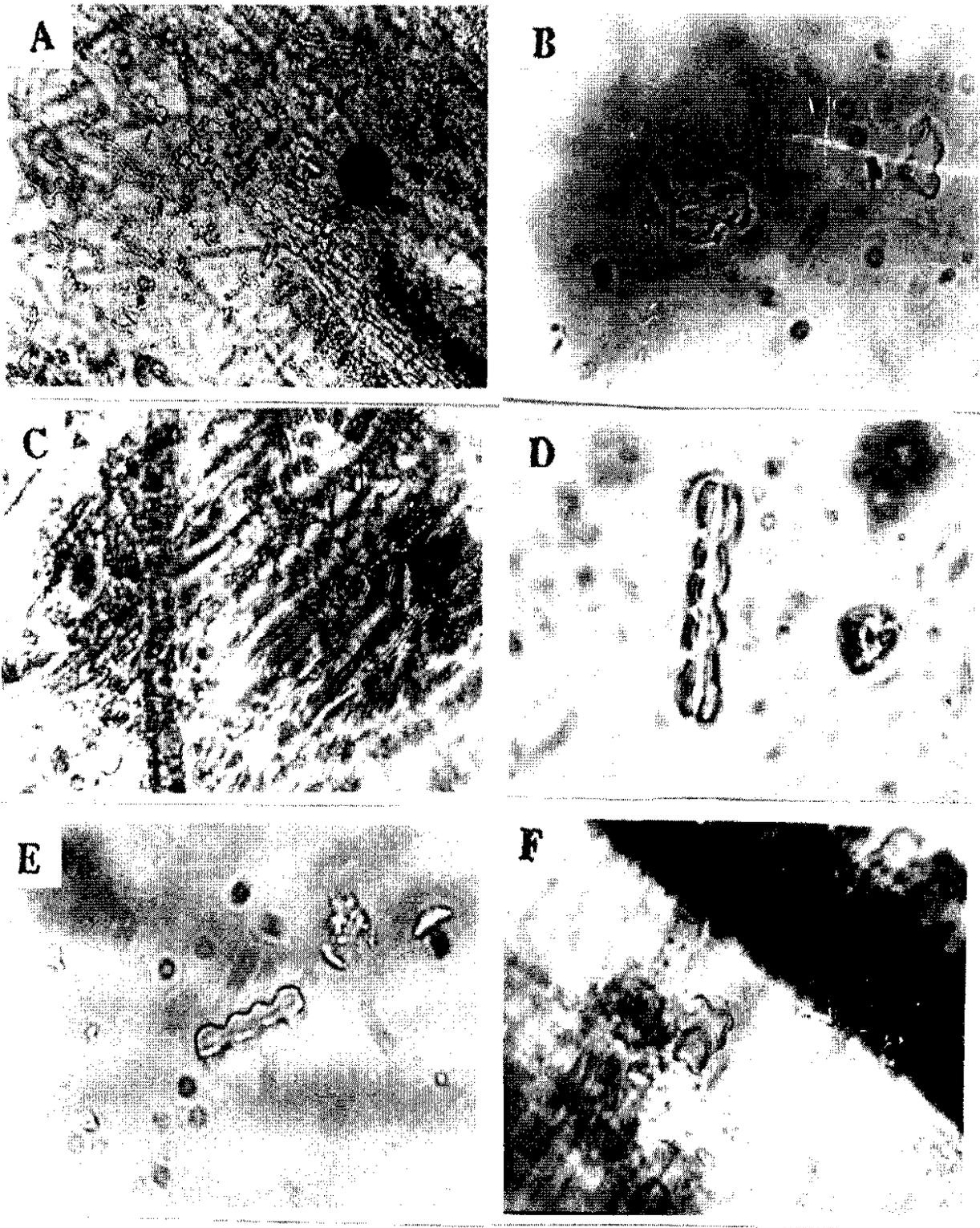


Fig. 3: Light micrographs showing opaline silica in the adaxial surface of leaves. A. *Panicum turgidum* x150, B. *Panicum turgidum* x600, C. *Cyperus rotundus* x600, D. *Sporobolus marginatus* x600, E. *Setaria verticillata* x600, F. *Andropogon aucherii* x600

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Table 1: Name of Species collected from different localities

S.No.	Name of Species	Locality	Collector
1.	<i>Chloris barbata</i> Swartz	Karachi University Campus, Chemistry Department.	S.S. Shaukat and G.R. Sarwar 809 (PEL).
2.	<i>Dichanthium annulatum</i> (Forssk.)	Safari Park, Guishan-e-Iqbal.	S.S. Shaukat and G.R. Sarwar 816 (PEL).
3.	<i>Eragrostis pilosa</i> (L.) Beauv.	Karachi University Campus, Botany Department.	S.S. Shaukat and G.R. Sarwar 810 (PEL).
4.	<i>Panicum turgidum</i> Forssk.	North Nazimabad, Hyderi, Karachi.	G.R. Sarwar 406 (PEL).
5.	<i>Eragrostis poaeoides</i> Beauv.	Karachi University Campus, Physics Department.	S.S. Shaukat and G.R. Sarwar 811 (PEL).
6.	<i>Bracharia ramosa</i> (L.) Stapf.	Safari Park, Gulshan-e-Iqbal.	S.S. Shaukat and G.R. Sarwar 815 (PEL).
7.	<i>Sporobolus marginatus</i> Hochst. ex A. Rich.	Malir Cant. Karachi.	G.R. Sarwar 409 (PEL).
8.	<i>Setaria verticillata</i> (L.) Beauv.	North Karachi, Sector 10, Karachi.	G.R. Sarwar 412 (PEL).
9.	<i>Andropogon aucheri</i> Boiss.	Karachi University Campus, Behind CDR!	S.S. Shaukat and G.R. Sarwar 812 (PEL).
10.	<i>Dactyloctenium aegyptium</i> (L.) Beauv.	Karachi University Campus, Near Silver Jubilee	S.S. Shaukat and G.R. Sarwar 813 (PEL)
11.	<i>Cenchrus pennisetiformis</i> Hochst.	North Karachi, Sector 10, Karachi	G.R. Sarwar 414 (PEL).
12.	<i>Lasiurus hirsutus</i> (Forssk.) Boiss.	North Karachi, Sector 10, Karachi.	G.R. Sarwar 410 (PEL).
13.	<i>Cynodon dactylon</i> (L.) Pers.	North Nazimabad, Hyderi, Karachi.	G.R. Sarwar 408 (PEL).
14.	<i>Saccharum munja</i> Roxb.	Karachi University Campus, Near Hotel.	S.S. Shaukat 814 (PEL).
15.	<i>Aristida mutabilis</i> Trin. at Rupr.	Nazimabad No. 2, Karachi.	G.R. Sarwar 413 (PEL).
16.	<i>Cyperus rotundus</i> L.	North Nazimabad, Hyderi, Karachi.	G.R. Sarwar 411 (PEL).
17.	<i>Cyperus bulbosus</i> Vahl.	North Nazimabad, Hyderi, Karachi.	G.R. Sarwar 407 (PEL).

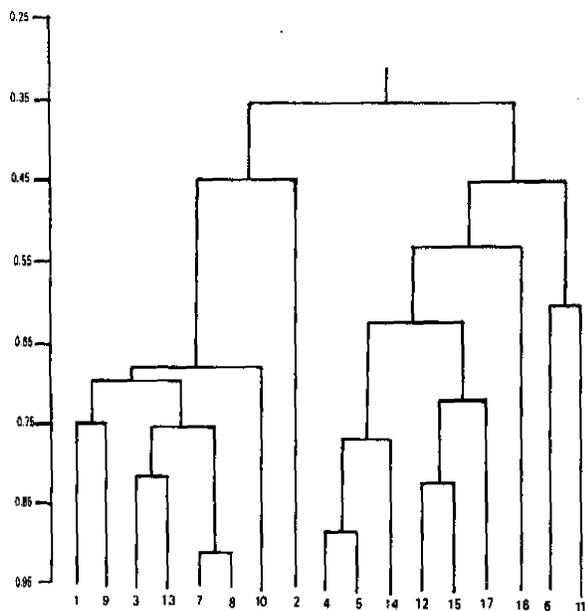


Fig. 4: Dendrogram derived from agglomerative hierarchical clustering of 17 species based on opaline silica characteristics

same size (Table 1).

Square-shaped phytoliths: Square-shaped phytoliths were observed in *Chloris barbata* (Fig. 1c) and *Bracharia ramosa* (Fig. 2e, f). Opal phytoliths were arranged in two to three rows in *Bracharia ramosa* (Fig. 2e, f) whereas in *Chloris barbata* (Fig. 1c), they were sparsely scattered. *Andropogon aucheri* (Fig. 3f) was the only species which had square-shaped phytolith with an appendage (Table 1).

Saddle-shaped: Saddle-shaped phytoliths were found only in one species i.e. *Saccharum munja* (Fig. 1g). They were costal, arranged in three rows on adaxial surface.

The dendrogram resulting from the average linkage clustering (Fig. 4) showed two major groups I and II. Group I usually includes taxa with either randomly distributed phytoliths or arranged in one row, with their length ranging from 20 to 30 μm and density from 1-3 phytoliths per μm and with mostly intercostal arrangement. By contrast group II comprises of taxa with phytoliths usually arranged in two to three rows, with lengths greater than 30 μm and density mostly between 3-7 per μm with costal distribution.

Discussion

The use of light microscope to study intact and isolated silica deposits in the leaves of different species adds

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significantly to our knowledge of their shape, structure and distribution pattern. During studies, five types of opaline phytoliths were observed i.e. dumb-bell-shaped, rod-shaped, square-shaped, sphere-shaped and saddle-shaped. These shapes have previously been noticed by earlier workers in different grasses (Baker, 1959; Twiss *et al.*, 1969; Blackman, 1971; Sangster, 1978).

Dumb-bell shape opaline phytoliths was found to be most common. It was found in 8 out of 17 taxa studied. Whereas rod, sphere and saddle-shaped phytoliths were found in one species each. Dumb-bell-shaped phytoliths were further classified with respect to their distribution. In *Dichanthium annulatum*, *Panicum turgidum*, *Eragrostis poaeoides*, *Bracharia ramosa*, *Cyperus rotundus*, *Cyperus bulbosus*, *Lasiurus hirsutus*, *Cynodon dactylon*, *Saccharum*, *nunja* and *Aristida mutabilis*, they were arranged in one to three rows in the form of chains, while in *Chloris barbata*, *Eragrostis pilosa*, *Sporobolus marginatus*, *Setaria vertiala*, *Andropogon aucherii*, *Dactyloctenium aegyptium* and *Cenchrus pennisetiformis*, they were distributed sparsely and without any definite pattern. In some species the lobes were bigger and the connecting rod was small e.g. *Aristida mutabilis* (Fig. 1a), while in *Panicum turgidum* (Fig. 1a, b), the lobes were smaller with the connecting rod relatively longer e.g. *Cyperus bulbosus*. The dumb-bell shape is considered diagnostic for the Gramineae by Twiss *et al.* (1969). The variation in the dumb-bell-shaped observed could have a great potential as a diagnostic character, in addition to other diagnostic characters. Geis (1973) considered that silicified epidermal hairs were lacking in grasses and found in deciduous forest species. Thus this character could be used to distinguish between grass species and deciduous forest species. Sphere, rod and saddle shapes found as less frequent forms could have a potential as diagnostic characters that could be helpful for identification purposes (Rapp and Mulholland, 1992). There is a great need for the study of the phytoliths in other grasses and sedges of this region to disclose this type of information of diagnostic value. In addition, the characteristics of opaline silica observed here can be used for identification of species during nonflowering season.

References

- Baker, G., 1959. Opal phytoliths in some Victorian soils and red rain residues. *Aust. J. Bot.*, 7: 64-87.
- Bennett, D.M. and A.G. Sangster, 1981. The distribution of silicon in the adventitious roots of the bamboo *Sasa palmata*. *Can. J. Bot.*, 59: 1680-1684.
- Bennett, D.M. and D.W. Parry, 1980. Electron-probe microanalysis studies of silicon in the elongating basal internodes of *Avena sativa* (L.), *Hordeum sativum* (Jess.) and *Triticum aestivum* (L.). *Ann. Bot.*, 45: 541-547.
- Blackman, E., 1971. Opaline silica bodies in the range grasses of southern Alberta. *Can. J. Bot.*, 49: 769-781.
- Borre, A.V. and L. Watson, 1994. The infrageneric classification of *Eragrostis* (Poaceae). *Taxon*, 43: 383-422.
- Everitt, B.S., 1980. *Cluster Analysis*. Wiley, New York, pp: 13.
- Geis, J.W., 1973. Biogenic silica in selected species of deciduous angiosperms. *Soil Sci.*, 116: 113-130.
- Gower, J.C., 1971. A general coefficient of similarity and some of its properties. *Biometrics*, 27: 857-871.
- Hart, D.M., 1988. The plant opal content in the vegetation and sediment of a swamp at Oxford Falls, New South Wales, Australia. *Aust. J. Bot.*, 36: 159-170.
- Kaufman, P.B., P. Dayanandan, Y. Takeoya, W.C. Bigelow, J.D. Jones and R. Ller, 1981. Silica in Shoots of Higher Plants. In: *Silicon and Siliceous Structures in Biological Systems*, Simpson, T.L. and B.E. Volcani (Eds.). Springer, New York, pp: 409-449.
- Lanning, F.C., T.L. Hopkins and J.C. Loera, 1980. Silica and ash content and depositional patterns in tissues of mature *Zea mays* L. plants. *Ann. Bot.*, 45: 549-554.
- Metcalf, C.R. and L. Chalk, 1983. *Anatomy of the Dicotyledons: II: Wood Structure and Conclusion of the General Introduction*. 2nd Edn., OUP Oxford, London, ISBN: 9780198545590, Pages: 330.
- Parry, D.W. and F. Smithson, 1958. Techniques for studying opaline silica in grass leaves. *Ann. Bot.*, 22: 543-549.
- Parry, D.W. and F. Smithson, 1964. Types of opaline silica depositions in the leaves of British grasses. *Ann. Bot.*, 28: 169-185.
- Parry, D.W., M.J. Hodson and R.H. Newman, 1985. The distribution of silicon deposits in the fronds of *Pteridium aquilinum* L. *Ann. Bot.*, 55: 77-83.
- Rapp, Jr. G. and S.C. Mulholland, 1992. *Phytolith Systematics: Emerging Issues*. Plenum, New York.
- Rovner, I., 1983. Plant opal phytolith analysis: Major advances in archaeobotanical research. *Adv. Archaeol. Method Theory*, 6: 225-266.
- Sangster, A.G., 1978. Silicon in the roots of higher plants. *Am. J. Bot.*, 65: 929-935.
- Sangster, A.G., 1983. Silicon distribution in the nodal roots of the grass *Miscanthus sacchariflorus*. *Can. J. Bot.*, 61: 1199-1205.
- Twiss, P.C., E. Suess and R.M. Smith, 1969. Morphological classification of grass phytoliths. *Proc. Soil Sci. Soc. Am.*, 33: 109-115.
- Watson, L. and M.J. Dallwitz, 1993. *Grass genera of the world: Illustrations of characters, descriptions, classification, interactive identification, information retrieval*. Australian National University, Canberra.
- Whang, S., K. Kim and W. Hess, 1998. Variation of silica bodies in leaf epidermal long cells within and among seventeen species of *Oryza* (Poaceae). *Am. J. Bot.*, 85: 461-466.
- Whang, S.S. and K. Kim, 1994. Opal phytolith morphology in rice. *J. Plant Bio*, 37: 53-67.
- Whang, S.S., 1993. *Phytolith morphology and its taxonomic significance in the genus onyza*. Ph.D. Thesis, Chonbuk National University, Korea.