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Silica Spicules in Canary Grass

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ABSTRACT

The hairs occurring on the surface and the persistent bracts of the fruits of canary grass (*Phalaris canariensis*) consist of opaline silica spicules emerging from the abaxial epidermal cells. They are approx. 500 μm long and taper from a diameter of 15 μm at the base to a tip radius of 0·3 μm. These spicules are found in the diet of people living in areas in which very high incidences of oesophageal cancer occur. The microstructure of cleaned spicules is complex and differs from that of mineral opal and also from tabashir, a plant opal occurring in bamboo, which is a relatively unstructured emulsion of silica particles.

Key words: *Phalaris canariensis*, silica deposits, silicification, hairs, electron microscopy, electron-probe, microanalysis.

Many plants absorb large quantities of dissolved silica which may be deposited during the growth of structural components such as rice husks to such an extent that it may furnish a commercial supply of biologically purified silica. Teak, bamboo and other hard wood may have concretions of silica but grasses, palms and nettles, for example, have highly organized structures, made largely of silica (Iler, 1979; Wynn Parry and Smithson, 1966). The silica, which can be isolated from the plant tissues by ashing or by acid digestion, has often been identified as opal by optical, electron, microscopial and X-ray diffraction techniques.

The nature of the structure of *Phalaris canariensis* fruit hairs is of interest with respect to their involvement in carcinogenesis, since fruits of such grasses are known to enter the wheat flour used in, for example, N.E. Iran (O'Neill *et al.*, 1980). The question as to whether there is active transport and/or controlled deposition of silica seems in this case to be clear since the hairs are well formed and regular structures so that silica is by no means only an excreted residue randomly deposited. The organization is complex and comparable to that in diatoms (Iler, 1979) and sponge spicules.

Scanning electron microscopy of the bracts and fruit of *P. canariensis* showed the hairs (Fig. 1A, B) to consist of a sheath 500 μm long tapering from 15 μm at the base to a radius of 0·3 μm at the tip. The surface is smooth and featureless but growth patterns, reminiscent of the myelin sheath of nerves and consisting of layers of silica could be observed on fracture or sectioning. The immediate surface layer (thickness 15 nm) is of denser material. Energy dispersive X-ray analysis (EDXA) of whole fruits, isolated hairs (Fig. 1C, D) and sectioned hairs (Fig. 1E) detected only silicon and no elements of higher atomic number. The lemma is also rich in silicon. X-ray diffraction showed the silica to be amorphous. The hairs were cleaned with nitric acid, embedded in Araldite and sectioned for examination and transmission electron microscopy. At low magnifications a double coaxial, eccentrically-arranged sheath structure was visible perhaps like a roll,

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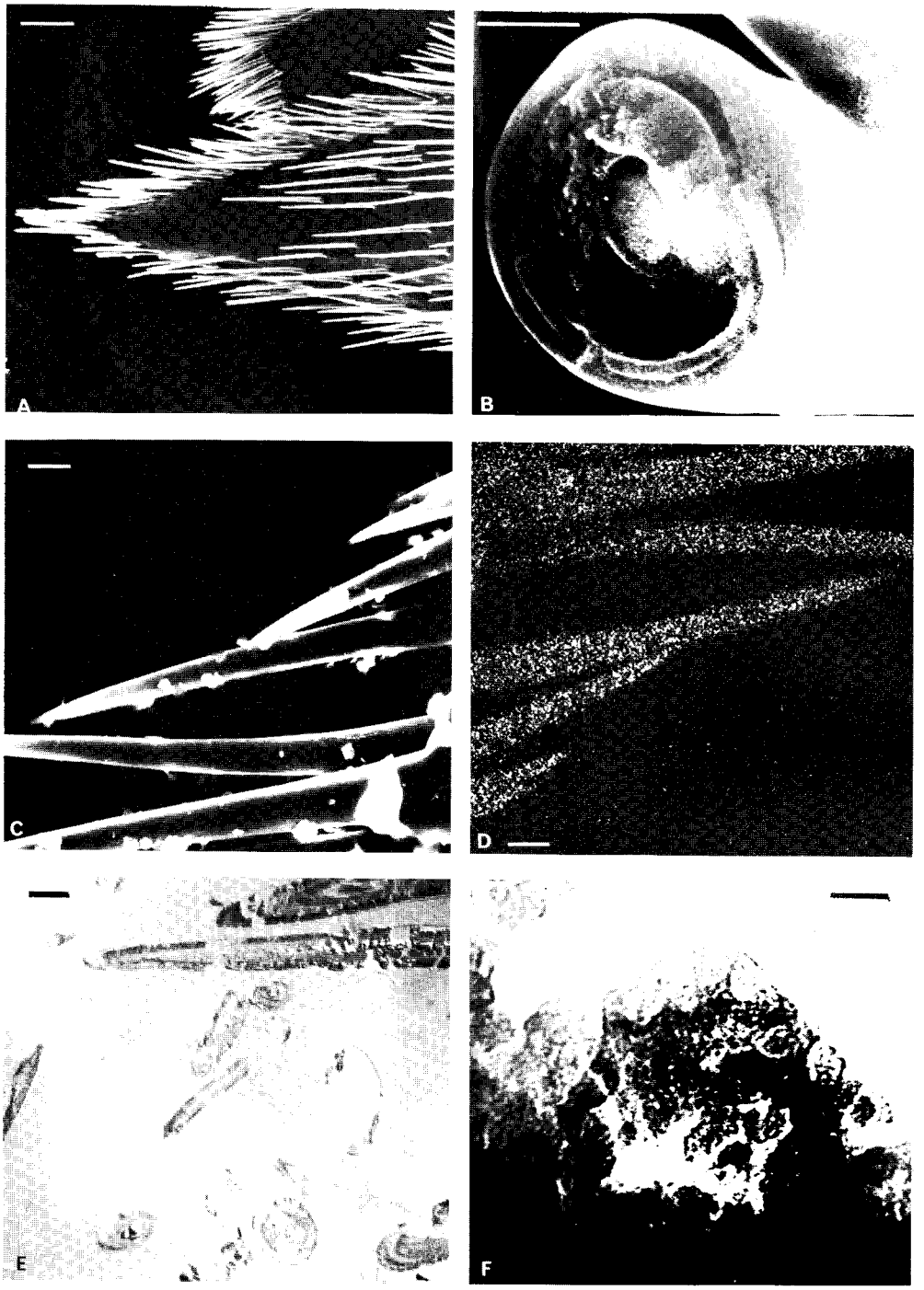

FIG. 1. A. Scanning electron micrograph showing fruit hairs of *Phalaris canariensis*. Bar = 150 μm. B. Cross section of fruit hair near base showing layers of silica. Bar = 2 μm. C, D. Secondary electron and X-ray distribution images of hairs and lemma showing the distribution of silica. Bar = 10 μm. E. Light micrograph of 1·0 μm section through fruit hairs showing the double co-axial eccentrically arranged sheath structure. Bar = 10 μm. F. Fundamental unit particles of 6–8 nm diameter. Bar = 80 nm.

although no external seam was visible. High resolution microscopy of sectioned and crushed material showed apparently fundamental units, approximately spherical and of 6–8 nm diameter, arranged hierarchically into small flakes, then into rather poorly defined sheets, which were wrapped around the spicule axis (Fig. 1F). The fundamental unit particles appear to be like those in tabashir ['sugar of bamboo' an ancient and present day item of the Unani pharmacopoea (Watt, 1889)] as well as those of opals of inorganic origin. The latter are reported to consist of unit particles about 3 nm in diameter arranged in three or four spherical shells like a hailstone to give a sphere of some 100 nm diameter. Tabashir is reported (Jones, Milne and Sanders, 1966) as containing particles of about 10 nm diameter which were associated into much less organized chains or clumps. The basic particles of the fruit hair are laid down in layers so as to form microplatelets which are seen on sectioning material. The mechanism of the deposition of silica is not known in terms of the process of silicic acid polymerization. The structure reported here is not like that of opal phytoliths which were larger and more irregular than the fundamental units found.

The finding that particles of silica are formed and arranged in an organized way into spicules is of significance from the point of view of plant cell morphogenesis and also for the involvement of plant silica in carcinogenesis (O'Neill *et al.*, 1980, 1982; Wynn Parry and Hodson, 1982) in which it may parallel some of the mechanical effects of asbestos fibres on cell growth.

[Our attention has been drawn to a paper (Mann *et al.*, 1983) which appeared while our paper was in course of publication. They report amorphous silica from various sources including *P. canariensis*, but do not report the fundamental unit particles of 6–8 nm which we show in Fig. 1F.]

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