On the Fine Structure of Bamboo Fibres

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Summary. The thick-walled bamboo fibres exhibit a polylamellate structure with alternating broad and narrow lamellae. Characteristically the cellulose fibrils in the broad lamellae are oriented almost parallel to the longitudinal axis of the fibre (2–20°), whereby there is a gradual but only slight increase in the angle from middle lamella to lumen. The narrow lamellae consist of fibrils oriented almost perpendicular to the cell axis (85–90°); this angle remains constant in all the successive narrow lamellae. The concentration of lignin is higher in the narrow lamellae than in the broad ones. Xylan seems to occur in a higher concentration in the narrow lamellae. The pits between the fibres are bordered. The results are discussed in relation to earlier data on wall structure and development. A model for the thick-walled bamboo fibre is presented with a new terminology for the various lamellae.

Introduction

The bamboos constitute an economically important group of plants especially in Asia. Because of their intensive use for constructional purposes as well as for pulp and paper, their anatomy has been studied by several authors [cf. Ghosh, Negi 1959; Yu, Chang 1963; Grosser 1971; Grosser, Liese 1971]. In spite of these general anatomical studies, the fine structure of bamboo fibres, which constitute the major cell type of the culm, has been only sparsely investigated, and most of this work was carried out decades ago. Structural details were examined by means of swelling experiments [Lüdtke 1928; Schlottmann 1933; Herzog 1938; van der Houwen van Oordt-Hulshof 1957; Tono, Ono 1962a, b,], by x-ray analysis [Preston, Singh 1950, 1952] and transmission electron microscopy [Kutscha 1965, Krishnagopalan et al. 1975]. Of particular interest was the structure of the thick-walled, lamellated fibres present in the vascular bundles of certain species. These investigations have revealed only partially the fine structural aspects of the lamellated fibres. Therefore within the frame-work of an extensive study on the fine structure of various bamboo cells the ultrastructure of these fibres has been investigated by several different techniques, the results of which are presented in the following.

* We are thankful to Mrs. R. Schultze and Miss B. Schröder for their technical assistance. Grateful acknowledgement is also due to Dr. D. Keyser and Mrs. K. Hoffmann for the SEM facilities and to Prof. Dr. J. Bauch and Mrs. R. Endeward for the UV-microspectrophotometry. Prof. T. E. Timell (Syracuse) and Dr. O. Faix were helpful with the preparation of hydrofluoric acid concentrations.
Materials and methods

The following species were studied:

Cephalostachyum pergracile Munro
Dendrocalamus latiflorus Munro
Dendrocalamus strictus (Roxb.) Nees
Melocanna bambusoides Trin.
Oxytenanthera abyssinica (A. Richard) Munro
Phyllostachys edulis A. & C. Riv.
Thysrostachys oliveri Gamble.

The samples were mostly air-dry, taken from internodes of mature culms. Fibre bundles were prepared from the peripheral region, where the lamellated, thick-walled fibres are most frequent. Some of the samples were delignified using the method of Dietrichs and Zschirnt [1972]. The light microscopic studies were performed with sections cut from FAA-fixed specimens or from resin-embedded material. Observations with the polarization optics were made using 2 μm thick sections. For swelling of fibres the sodium-chlorite delignified samples were macerated using Jeffrey's method. The fibres were floated in a thin film of water and put under a cover glass. Using Schweizer's reagent (CuOxam), they were swollen by withdrawing water with a filter paper. Photographs were taken using Nomarski interference optics.

Samples used for x-ray diffraction consisted of fibre bundles isolated from the tissue by maceration. They were examined with a Philips instrument (Co-Kα/35 kV/16 mA/specimen-film distance: 40 mm/diameter of samples: 0.8 mm/exposure time: 3 hrs/beam perpendicular to the longitudinal cell axis). For UV-microspectrophotometry 1 μm thick sections were prepared from specimens embedded in Spurr's medium or Epon 812. Using a Zeiss UMSP-I, both local absorption spectra of individual wall lamellae as well as scanning spectra across the wall width were taken. In addition UV-photographs were analyzed. For transmission electron microscopy both lignified and delignified samples were dehydrated in acetone and embedded in Spurr’s medium. Sections were cut with a diamond knife on a Porter-Blum Ultramicrotome, stained in Reynold’s lead citrate and observed in Siemens electron microscopes I and 101.

Lignin skeletons of fibres were prepared from 1 mm cubes or 50 μm longitudinal sections by treatment with hydrofluoric acid [Côté et al. 1968]. The thin sections were poststained in 2% aqueous potassium permanganate. Xylanase isolated from commercial preparations [Sinner et al. 1976] was used to obtain information on the ultrastructural distribution of xylan in the bamboo fibre wall. Thin sections of hemicellulose material were treated with xylanase for 48 hours and subsequently observed in the electron microscope.

Fixed samples were dehydrated in acetone for scanning electron microscopy. Air-dry samples were boiled in water and dehydrated by the solvent exchange method [cf. Thomas, Nicholas 1966]. Some of the air-dry samples were broken parallel to the grain in a tensile testing machine. All specimens were coated with gold in a sputter coater and examined in a Cambridge Steroscan microscope.