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SHORT NOTES

FIGURES OF THE WOOD OF *KHAYA IVORENSIS* AND *MILLETTIA LAURENTII*

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ABSTRACT

This report describes the natural figures of wood samples collected from the main trunks of *Khaya ivorensis* A. Chev. and *Millettia laurentii* De Wild. trees. The figures have been analyzed in relation to such cambial growth events as the oriented cellular phenomena in the meristem and the changes taking place during wood cell differentiation.

KEYWORDS: *Khaya ivorensis, Millettia laurentii*, oriented cambial events, storeyed cell arrangement, wood grains.

INTRODUCTION

'Figure' is a term, which is used in wood science to describe the appearance of longitudinal surfaces of wood, which is determined partly by the wood grain and partly by the cut and the innate properties of the wood. Wood grains emerge basically from the patterns of growth behavior of cambial cells and the subsequent processes taking place during wood cell differentiation. The different types of figures that appear in the wood are thus related, directly or indirectly, to the oriented morphogenetic events such as the anticlinal cambial cell divisions, intrusive growth of cell tips, elimination of initials, and the splitting and fusion of rays in the left (S) or right (Z) configuration, which are correlative to time and space and become visible on the tangential surface of the cambium (Hejnowicz 1990, 2002). These cellular events of the cambium, which tend to occur either in the Z or S orientation, give rise to specific sectors called 'the cambial domains' that are characterized by a unidirectional orientation of cell endings (Hejnowicz 1964). Within a Z-type of domain, not only the anticlinal divisions and apical overlappings of intrusively growing fusiform initials but also the splitting and uniting of rays are tilted in right hand direction, whereas all these events exhibit a left hand orientation in a S-type domain. It is known that the cambial domains vary in shape and height and migrate vertically in relation to time (Hejnowicz and Romberger 1979). In general, figures are based largely on the types of wood grain: straight, spiral, wavy and interlocked (Harris 1989). The spiral, wavy and interlocked grains differ in wavelength, which determines the axial dimension of the cambial domains. Irregular and complex grain pattern may also be formed either by a superposition of simple patterns, or by the local disturbances in cell orientation (Hejnowicz and Romberger 1979, Krawczyszyn and Romberger 1980).

On the basis of the arrangement of fusiform cambial initials, which reflects also in the alignment of the axial wood elements, the storeyed, non-storeyed and transitional (intermediate) types of cambium are recognized (Bailey 1920, Iqbal and Ghouse 1990, Włoch et al. 2002). In the non-storeyed cambia, typical of conifers and most of dicotyledons, the adjacent fusiform initials do not end at the same height level but the tips of young sister initials elongate to varied extents, following the pseudotransverse anticlinal cell division, thus overlapping each other and making the different cells terminate at different levels of height (Bannan 1950, Romberger et al. 1993, Larson 1994, Iqbal 1995, Tulik 2001). In storeyed cambia, which are restricted to some advanced families of dicots, the ends of the fusiform initials terminate almost at the same height level, thus enabling the initials to form regular, horizontal rows placed one above the other, as visible on the tangential surface of the meristem (Philipson et al. 1971, Zagórska-Marek 1977, Iqbal and Ghouse 1990). Some species possess double storied cambium, wherein both the fusiform and ray initials form horizontal tiers (Iqbal and Ghouse 1990, Kojs et al. 2003, Iqbal et al. 2005, Myśkow and Zagórska-Marek 2008).

The structural changes that occur in wood cells during the process of differentiation give rise to figures in the wood. These changes are connected primarily to the enlargement of the cambium-derived cells and the cell wall architecture. Some changes, like the formation of tyloses and deposition of secondary metabolites such as phenolic compounds, take place during heartwood formation (Hillis 1987). The colour of the wood and the size, shape and distribution of wood cells are considered to impart a diagnostic look to the wood of a given species. Figures in the wood are also known to be influenced by various environmental factors (Pyszyński 1990, Wodzicki 2001).

Khaya ivorensis A. Chev. (African mahogany), a Meliaceae, and *Millettia laurentii* De Wild. (African rosewood), a Fabaceae, are native to Africa. The woods of these trees are unique in colour and grain patterns and form a valuable material in the wood industry. In consequence of its excessive felling for use as a commercially important timber, and the consequent habitat destruction, *Millettia laurentii* is now placed on the IUCN Red List of endangered species.

This study was undertaken to understand the wood figures in *K. ivorensis* and *M. laurentii* in relation to the oriented cell growth phenomena in the cambium and the subsequent differentiation of wood cells.

MATERIAL AND METHODS

Wood samples of the main stem of *Khaya invorensis* and *Millettia laurentii* trees were obtained from the wood collection of the Faculty of Wood Technology in the Warsaw University of Life Sciences – SGGW. The surfaces of the samples were polished and photographed with OLYMPUS SZX9 steroscopic microscope equipped with a digital acquisition system. For microscopic examinations, the samples containing wood increments of heartwood were cut off and boiled for a few days in the solution of glycerin, water and ethyl alcohol (1:1:1) in order to soften the wood. Later, the longitudinal (both tangential and radial) and transverse sections were cut on HM 440E sliding microtome (Microm International GmbH) at a thickness of approximately 30 µm. Finally, the unstained sections were transferred on to glass slides, fixed in glycerin and examined. Some selected sections were photographed by using the Olympus BX61 motorized microscope system equipped with digital color camera DP70 and Cell P software. In order to determine the shape and size of individual wood elements, the wood blocks were cut into small pieces and macerated for a few hours in a mixture of H_2O_2 (36 %) and acetic acid, 1:1 (v/v), at 100°C in a water bath. The macerated tissue was washed and examined under microscope using the Nomarski contrast method.

RESULTS AND DISCUSSION

Both of the species are characterized with diffuse-porous wood, differing in structural details.

Khaya ivorensis A. Chev.

The *Khaya* heartwood is pink or reddish brown, with visible grain on the radial surface (Fig. 1). The alignment of the wood cells, as seen in the radial longitudinal sections, is not parallel to longitudinal axis of the stem but a little inclined sideways, forming a wavy-grain pattern with a wavelength (axial dimension of domains) of several centimeters. Similar axial size of domain, varying from few to many centimeters, was observed in the wavy-grained woods of *Platanus* (Krawczyszyn 1972) and *Betula* (Hejnowicz and Romberger 1973). In the interlocked grain of *Entandrophragma*, the wavelength was as long as up to several meters (Hejnowicz and Romberger 1979). As already mentioned, the wood-grain pattern could be interpreted as a historical record of the cambial cell behavior, demonstrating the capability of cambial initials for undergoing intense inclination changes due to oriented cellular events such as the pseudotransverse divisions of fusiform cells and the occurrence of split and fusion of rays. This also indicates that orientation of the initials at a given point of cambial surface changes cyclically and thus the cellular sectors of Z orientation are alternated with those of S orientation (Krawczyszyn 1972, Hejnowicz and Romberger 1979).

Fig. 1: The wavy grain figures on the radial surface of Khaya ivorensis wood that result from wavelike changes of inclination of the cambial initials producing the wood elements. The grain figures are visible due to differences in grain inclination, which evoke differences in light reflection – the slightly oblique brighter and darker stripes alternate on the radial face of Khaya wood.

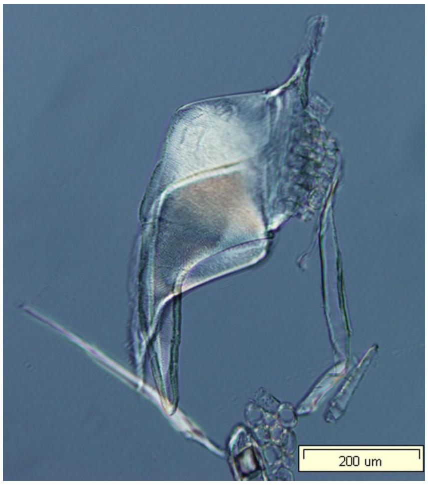

Fig. 2: The tail-like protrusions on both ends of a macerated vessel member of Khaya ivorensis wood as observed with the Nomarski contrast.

For decorative aspects, wavy grain pattern is highly prized although, on the other hand, it is considered as a defect in timbers for construction (Weddell 1960).

Growth rings in the wood are inconspicuous. The diameter of vessels, occurring solitary or in radially oriented clusters, measures up to about 280 μm. The vessel elements bear simple perforation plates and show tail-like protrusions at both ends in the macerated samples (Fig. 2). These protrusions were generally longer at one end than at the other. On the tangential surface of wood, both typical (linear) and atypical (zigzag) vessel patterns were visible (Fig. 3), showing perforated vessel elements arranged in a linear fashion as well as in the so-called zigzag manner respectively (Andrè 2000). The zigzag-running vessels comprise of two linear and parallel separate vessels that are connected to each other by short files of vessel members covering the intervening distance. Andrè (2000) reports that the zigzag vessels are located usually in the nodes, on each side of the bulging insertion zone of petioles and axillary branches, but often they are also seen in the tangential sections of the normal wood. The zigzag vessels in the wood are probably an outcome of disturbances in the polar auxin transport, which plays a key role in the process of wood morphogenesis (Wodzicki 2001).

The axial parenchyma of the *Khaya* wood is mainly paratracheal vasicentric. The lumens of vessels and parenchymatic cells are filled with a brown substance (Fig. 4). The groundmass of the wood comprises of thick-walled fibres. The rays, mostly multiseriate with cells filled with starch, are heterogeneous and contain squarish upright cells, which is typical of the tropical woods.

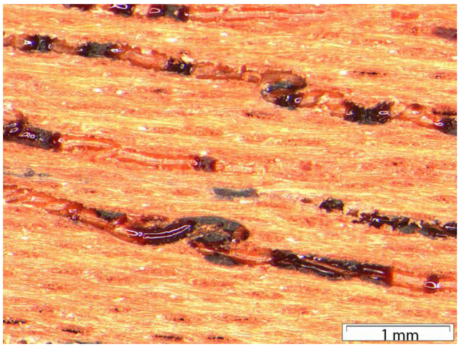

Fig. 3: The classical zigzag pattern of vessels, as seen in the tangential longitudinal sections of Khaya ivorensis wood.

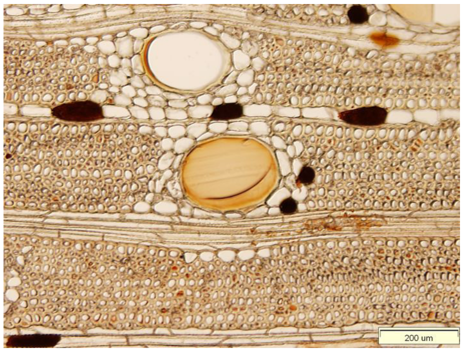

Fig. 4:. Transverse section of Khaya ivorensis wood showing the vessels and parenchymatous cells filled with brown substances.

Millettia laurentii De Wild.

The *Millettia* heartwood is dark brown. It shows straight-grain pattern, indicating that the frequency of morphogenetic cambial events, in comparison to *Khaya*, is more balanced and too low to evoke a wavy-grain formation.

The annual wood increments are distinct, making the boundaries of growth rings conspicuous. The wood exhibits distinct zones of light-colour parenchyma and dark-stained fibers (Fig. 5), thus pointing to a sequential differentiation of wood elements. The parenchyma tissue is paratracheal, vasicentric to confluent, and occurs in the form of streaks alternated with fibre population. Vessel elements have simple perforation plates. The vessels are gathered in radial files and their average radial diameter goes up to 350 µm. The multiseriate rays in *Millettia* are more homogeneous than in *Khaya* and consist of radially elongate cells alone.

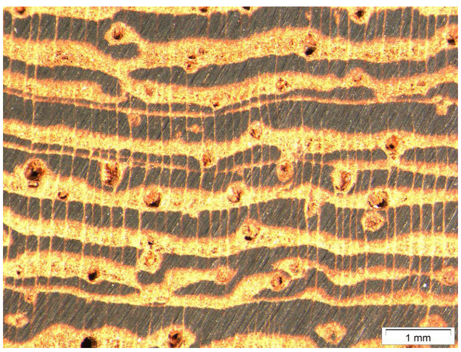

Fig. 5: Transverse section of Millettia laurentii wood showing the alternate lighter and darker zones consisting of two different structural elements deposited by the cambium periodically.

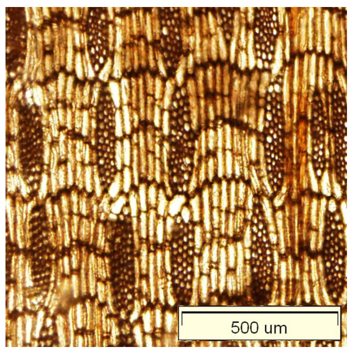

Fig. 6: Tangential longitudinal section of Millettia laurentii wood, showing the storeyed arrangement of axial parenchyma, vessel elements and rays.

An interesting feature of the *Millettia* wood is the storeyed pattern of its component elements (Fig. 6).

Horizontal rows of rays are arranged within the storeys of cells derived from fusiform initials, thus pointing to the double-storeyed nature of the cambium. The storeyed pattern could be related to periodic changes in the inclination of fusiform initials that lead to the splitting of long rays as, for instance, in *Entandrophragma cylindricum* (Hejnowicz and Zagórska-Marek 1974) and *Tilia cordata* (Włoch 1985). Myśkow and Zagórska–Marek (2008) postulated, on the basis of their study of *Aesculus turbinata*, that the double-storeyed phenotype is based on vertical migration of rays caused by a controlled polar modification of rays in which new ray cell initials are consistently added at one end of the ray whereas the existing cells are eliminated at the opposite end. These cell events continue to be in progress until the rays have been so transformed as to fit within the confines of horizontal stories of the fusiform initials. Kojs et al. (2004a, b), on the other hand, have ascribed the readjustment of fusiform cambial initials and their stratification in *Lonchocarpus sericeus* and *Wisteria floribunda* to the apical intrusive growth of these initials along the tangential surface of their neighbouring cells. The same intrusive growth of fusiform initials was found to be responsible for rearrangement of rays in the cambium (Wilczek et al. 2011).

Mechanism of cambial cell stratification in *Millettia* is yet to be studied in detail, but the arrangement of the component wood cells in this species seems to be correlative in time and space to the periodic arrangement of the mother initials in the cambium.

CONCLUSIONS

The present study suggests that:

- Wavy grain figure in the wood of *Khaya ivorensis* stems derived from the rapidly occurring oriented cellular events in the cambium.
- Presence of a zigzag pattern of vessels in the wood of *Khaya ivorensis* points to disturbances during wood cell differentiation.
- The frequency of oriented cellular events in the cambium of *Millettia* is too low to evoke the wavy grain pattern.
- The cambium of *Millettia* is double storeyed, with both rays and fusiform initials arranged in horizontal tiers.

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