COMPARATIVE STRUCTURE OF VASCULAR CAMBIUM AND ITS DERIVATIVES IN SOME SPECIES OF STERCULIA

by

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SUMMARY

Structural variations in cambium, xylem and phloem collected from main trunks of Sterculia colorata, S. alata, S. villosa, S. urens and S. foetida growing in the South Dangs forests were studied. In all five species, the cambium was storied with variations in the length of fusiform cambial cells. Compared to other species S. foetida had the longest and S. urens the shortest fusiform cambial cells. Cambial rays in all the species were compound (tall) and heterocellular with sheath cells. Their height and width were maximal in S. foetida and in S. villosa respectively. In all the species the storied nature of fusiform cambial cells was maintained in derivative cells that developed into sieve tube elements, vessel elements and axial parenchyma of both phloem and xylem. However, fibres of phloem and xylem were nonstoried. The dimensions of elements in phloem and xylem varied among the species. The variation in the mean length of sieve tube elements and vessel members coincided with that of fusiform cambial cells.

Key words: Vascular cambium, phloem, Sterculia.

INTRODUCTION

Structure of cambium differs from species to species with respect to the shape, size, length, width and arrangement of fusiform cambial cells and cambial ray cells. Based on the arrangement of fusiform cambial cells, two types of cambia are recognised, storied and nonstoried. Nonstoried cambium is more prevalent in plants than the storied one (Ghouse & Iqbal 1975; Ghouse & Hashmi 1977; Rao & Dave 1981, 1982; Silva et al. 1990). Hence more information is available on structural and seasonal variations of nonstoried cambium. Occurrence of storied cambium is reported in few tropical genera and considered to be more advanced than the nonstoried one (Bailey 1923; Paliwal & Prasad 1970; Ghouse & Yunus 1974a, 1974b; Yunus et al. 1978; Rao & Dave 1984). The occurrence and general organisation of the vascular cambium in many tropical tree species remains unknown. It is well known that length and width of cambium cells and their derivatives differ by age and height level within the same tree (Furqan & Ahmad 1981; Iqbal & Ghouse 1983; Khan & Kalimullah 1991), but little information is available on the comparative studies on the vascular cambium and its
Fig. 1. – A, B, E, F, H = tangential view; C, D, G, I, J = transverse view. – Storied arrangement of fusiform cambial cells in Sterculia colorata (A), S. alata (B), S. villosa (E), S. urens (F) and S. foetida (H); × 75 (FCC = fusiform cambial cells; RCC = ray cambial cells; arrowhead = sheath cells. – Distribution of axial parenchyma in S. colorata (C), S. villosa (D), S. urens (G), S. alata (I) and S. foetida (J); × 75.
derivatives in different species of same genus (Ghouse et al. 1976). The present study is aimed to ascertain the presence of storied cambium in other species of *Sterculia* in addition to *S. urens* and *S. foetida* (Ghouse et al. 1973) and reports the variation of anatomical characteristics of secondary xylem and phloem.

**MATERIALS AND METHODS**

Samples of cambial tissue together with the outer xylem and inner phloem were collected from main trunks at breast height of the trees of *Sterculia colorata*, *S. alata*, *S. villosa*, *S. urens* and *S. foetida* growing in South Dangs, a moist deciduous open forest of Waghai region, Gujarat State (India). Three trees of each species having a more or less similar age (13–15 years) and trunk diameter (45–50 cm) were selected to obtain two blocks from each tree. Samples measuring about 60 × 20 mm were taken using a chisel, hammer and single edge blade and immediately fixed in FAA (Berlyn & Miksche 1976) in the second week of January 1995. Small blocks measuring about 20 × 20 mm were cut from the sampled strips using a hacksaw. Suitably trimmed small pieces of these blocks were sectioned on a Ernst-Wetzlar sliding microtome in transverse and tangential longitudinal planes at a thickness of 12–15 μm. These sections were tied to slides with fine cotton thread and stained with tannic acid–ferric chloride–Lacmoid combination (Cheadle et al. 1953). After passing through an ethanol-xylene series they were mounted in DPX.

A one mm wide portion of xylem bordering the cambial zone was macerated with Jeffrey’s fluid (Berlyn & Miksche 1976) at 55–60°C for 24–36 hours. The average length of fusiform cambial cells, xylem fibres, vessel elements, sieve tube elements and height of cambial rays were calculated from a measurement of 100 elements from each block. Measurement of phloem cells was made directly from the tangential longitudinal sections. Vessel frequency was counted by using a projection disk mounted on the microscope. Fusiform and cambial ray cell ratio were estimated following the method of Ghouse and Yunus (1974b).

**RESULTS**

All the species of *Sterculia* investigated had storied cambium with axially elongated fusiform cambial cells and isodiametric cambial ray cells. In tangential section, fusiform cambial cells were roughly hexagonal while cambial rays were compound with marginal sheath cells (Fig. 1F).

The radial walls of the fusiform cambial cells were beaded due to the presence of numerous primary pit-fields. These cells underwent radial longitudinal division, resulting in two daughter cells of equal size. Although the overall organization of cambial cells was almost the same, the individual cell size, their relative number and proportion differed to a considerable extent among all the species. The size of cambial cells varied on average from 302–424 μm. Their length was shortest in *S. urens* (Fig. 1F) and longest in *S. foetida* (Fig. 1H).
Cambial rays were found to be compound, heterocellular with 1–3 layers of marginal sheath cells. Variation in length and width of cambial rays were found to be significant among all the species of Sterculia (Fig. 2 and 3) ranging from 839–2002 μm and 131–361 μm respectively. They were shortest (839 μm) in S. foetida (Fig. 1H).

The ratio of ray and fusiform cambial cells also differed between the different species investigated. Fusiform cambial cells constituted 60% of the tangential area in S. colorata, 56% in S. alata, 61% in S. villosa, 61% in S. urens, and 55% in S. foetida.

The secondary phloem in all the species of Sterculia consisted of sieve tube members, companion cells, axial and ray parenchyma cells and fibres. In transverse section phloem fibres appeared in more or less continuous tangential bands interrupted by rays except in S. alata where they were irregularly scattered among sieve tube members. Sieve tube members were the largest cells in transverse section. Companion cells occurring at the margins of sieve tube members were the smallest cells in transverse section. The axial parenchyma cells were intermediate in size between sieve tube members and companion cells and were often associated with bands of phloem fibres. They formed alternating bands of 3 or 4 cells with fibres.

Fig. 2. Histogram showing mean cambial ray height (μm) in Sterculia colorata (A), S. alata (B), S. villosa (C), S. urens (D), and S. foetida (E).

Fig. 3. Histogram showing mean width of cambial rays (μm) in Sterculia colorata (A), S. alata (B), S. villosa (C), S. urens (D), and S. foetida (E).
In non-conducting phloem, the sieve tubes along with companion cells become narrow and underwent obliteration. As a result the non-conducting phloem was composed of only parenchyma and fibres. However, the parenchyma cells were larger compared to those in the functional phloem. The sieve tube members had slightly inclined end walls with simple sieve plates. Lateral sieve area occurred on both radial and tangential walls. Variable amounts of callose were found on sieve areas of mature elements.

Compared with fusiform cambial cells the average length of sieve tube members was slightly less while the width increased (Fig. 4). The length of sieve tube members was found to be highest in *S. foetida*, i.e. 449 µm while shortest in *S. urens*, i.e. 291 µm among all the species studied (Fig. 4). Width of the sieve tube members varied from 25 µm to 37 µm in different species. However, maximum width was found in *S. villosa*, i.e. 37 µm and minimum width in *S. alata*, i.e. 25 µm.

Xylem in all the five species was found to be diffuse-porous with indistinct growth rings. However, the amount of wood produced during one growth period could be
determined by vascular ray noding and the presence of narrow lumen cells with thick walls in the latewood. Noding of vascular rays generally occurred in the region of the resting cambial zone. The size of the nodes varied in individual plants. In transverse section the nodes generally appeared spindle-shaped. The nodes may persist distinctly in the wood. However, the noding is not so distinct in some trees (Amobi 1973). The wood fibres were nonseptate and possessed narrow lumen. Fibres were 5–8 times longer than the fusiform cambial cells. Vessel element length was highest (450 μm) in S. foetida and lowest (285 μm) in S. urens. In all the five species, vessels were diffuse, solitary and in radial to tangential multiples of 2 or 3, round to oval with radial diameter ranging from 92–300 μm. In comparison to fusiform cambial cells, the length of vessel elements had decreased (Fig. 2) but the width increased 6–12 times. Perforation plates were simple in transverse to slightly oblique end walls. Intervessel pits were alternate, round to oval and 6–8 μm in diameter.

Axial parenchyma were vasicentric to aliform often forming distinct tangential confluent bands in S. colorata, S. alata and S. urens. While in S. villosa they were scanty paratracheal and diffuse apotracheal in S. foetida. Some of the xylem ray cells were filled with phenolic deposits in S. villosa and S. foetida. However, such deposition was not noticed in the other three species.

**DISCUSSION**

The vascular cambium in all of the species was storied. Radial longitudinal and anticlinal division in fusiform cambial cells help to maintain this stratified arrangement in the adult stem. Cambial rays were compound with 2 or 3 layers of sheath cells. The occurrence of sheath cells tends to be constant in many genera of Sterculiaceae (Metcalfe & Chalk 1983).

The distribution of fusiform and ray cambial cells in cambium is not consistent in the species studied. Kozlowski (1971) generalized that fusiform cambial cells occupy 90% of the total tangential area of cambial zone. However, studies on some Indian species of Dalbergia (Ghouse & Yunus 1974a) indicate that they occupy only up to 60% of the total tangential area of the cambial zone and their amount may fall as low as 25% in certain cases like Dillenia indica (Ghouse & Yunus 1974b). In the present study fusiform cambial cells in cambia of different Sterculia species did not exceed 75%.

In all the five species of Sterculia, sieve tube members were slightly shorter than the fusiform cambial cells. Zahur (1959) and Den Outer (1986) also reported the presence of shorter sieve tube elements. However, a slight decrease in length of sieve tube members may be due to the shifting of the pointed hexagonal tip of the fusiform cambial derivatives to transverse position in sieve elements (Anand et al. 1978).

Our study showed two wood anatomical groups in Sterculia species: (i) axial parenchyma aliform to confluent in S. colorata, S. alata and S. urens, vessel members short (length mainly less than 400 μm) and no deposition of phenolics in ray parenchyma and (ii) axial parenchyma scanty paratracheal in S. villosa and diffuse apotracheal in S. foetida, vessel member longer (length mainly more than 400 μm) and deposition of phenolics in ray parenchyma.
As compared with fusiform cambial cells, in all the five species of *Sterculia*, the width of vessel members increase 6–12 times and their length decreases slightly. The decrease in length may be due to the shifting of the pointed hexagonal tips to transverse position during the course of differentiation from fusiform cambial cell derivatives and also the radial expansion of developing vessel members. Anand et al. (1978) reported a slight decrease in length of sieve tube elements due to shifting of pointed hexagonal tips of fusiform cambial cells to transverse position.

Wood fibres exhibited a maximum increase in their length, i.e. 5–8 times the length of their precursors among all the species. This can only be attributed to the intrusive growth in these elements. This feature has also been reported in many other dicotyledonous taxa (e.g. Bailey 1920; Chattaway 1936).

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