Comparative Anatomy on the Structure of Vascular Cambium in Some Betulaceous Plants

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Abstract
A comparative study on the structure of vascular cambium of Betulaceous plants has revealed that the typical nonstoried cambium is composed of fusiform and ray initials in all plants examined. The size measurements of fusiform initials in tangential sections have revealed that the average length varies from 347.6-659.6 μm in the examined species, the maximum being in Alnus hirsuta and the minimum in Carpinus laxiflora. And then the length of fusiform initials depends on the length of the pseudotransverse end walls which undergo intrusive growth to varying extents in different species. In each species ray initials have their own size, magnitude, frequency of occurrence. The relative proportion of ray initials falls about 13.4-37.5%. Shrubby Corylus has lower proportion of ray initials than Alnus which possess wider trunk.

Key words: fusiform and ray initials, intrusive growth, length.

Introduction
The anatomical study of Betulaceae started with Moeller's(1876) description of the perforation type of the vessel member and the ray. Boubier(1896) reported on the pitting and the thickening pattern of the lateral wall of vessel member, the width of the ray and the aggregate ray. Moreover, the general anatomical characteristics of Betulaceae was also reported by Hoar(1916), Tippo(1938), and Metcalfe & Chalk(1950). Meanwhile, anatomical studies of Korean Betulaceae have been made such as the comparative study by the differences of vessel shape(Soh & Jeon, 1981) and the phylogenetic study in the xylem anatomy of the root(Soh & Lee, 1982). As above, all the anatomical studies of Betulaceae were conducted in the secondary xylem, therefore the studies of the vascular cambium itself are rare. Besides, most information about cambium has been obtained indirectly through anatomical studies of secondary xylem so far. Though the cambial activity is reflected in the secondary xylem, it is considered that there will be the structural differences due to the differentiational process between the initials and the derivative cells. Upon this, the study in the structural characteristics and the activity of the cambium, which is the origin of the secondary xylem, can be considered as very important in understanding both the differentiation process of xylem elements and the secondary growth of the tree. Thus, the present study has been conducted to clarify the structural characteristics of...
vascular cambium in the Betulaceae.

Materials and Methods

Cambial samples in the form of 2 cm² blocks, were collected from 11 species in 4 genera of Betulaceae which are grown in Chon-ju nursery garden of Korea Highway Corporation located in Ban-wol dong, Chon-ju. All samples were excised together with the bark and some sapwood, at approximately 1.5m from ground level. The blocks were fixed in FAA and later, aspirated for free access of the fixative to the interior of the tissues. After a week, all samples were rinsed in two changes of 50% ethanol and began the n-butanol dehydration series with No. 2. Subsequently, all samples were embedded with paraplast matrix in the 53-60°C oven. Sectioning was done serially on a Reichert's rotary microtome at a thickness of 10 μm in tangential plane. The sections were stained triply with haematoxylin, safranine and light green(Sass, 1971). After dehydration in an ethanol-xylene series, the sections were mounted in canada balsam for light microscopic study. The size measurements were made with micrometer scales. The value of mean and standard deviation of different elements was calculated on the basis of readings obtained for 200 elements measured at random out of all samples. The values for tapering end walls were obtained by measuring the slope of the end wall i.e., the wall which originates through a pseudotransverse division. The proportion of ray and fusiform initials was determined on the basis of their tangential plane following the method described by Ghouse & Iqbal(1975).

Results

The vascular cambium in the members of Betulaceae is composed of two types of initials, spindle-shaped element with long tapering end walls, fusiform initials, and roughly the isodiametric elements, ray initials. The tapering end walls of fusiform initials overlap each other to various degrees. Therefore, the vascular cambium is the typical non-storied or non-stratified(Fig. 1). On this cambium, the increase of the circumference in relation to the secondary growth was made through the pseudotransverse division of the fusiform initials and the subsequent intrusive growth of daughter cell(Fig. 1A).

The size measurements of fusiform initials in tangential sections have revealed that average length varies from about 347.6—659.6 μm, in investigated species, the longest being in Alnus hirsuta and the shortest in Carpinus laxiflora. Compared with other genera, it shows that Alnus has the longest fusiform initials followed by Betula, Corylus and Carpinus. The average diameter of the fusiform initials ranges from 14.4 ~20.5 μm, the maximum being in B. costata, and the minimum in C. coreana. However, unlike in length, the diameter variation of the fusiform initials does not tend to have regularity and differences among species and genera. The average length of the tapering end walls of fusiform initials ranges from 86.3~207.8 μm, the maximum being in A. hirsuta, which takes up 32% of the total length, and the minimum in C. laxiflora, it is about 25% of the total length. Judging by the above, there is a considerable variation among the species.

The ray initials were made up of isodiametric cells in all species investigated. But
Fig. 1. Photomicrographs show tangential views through cambial zones. ×300. A: Alnus hirsuta. Arrow indicates pseudotransverse division of fusiform initial. @: Fusiform initials, @: Ray initials. B: Betula costata. Arrow represents new ray initial is formed by cut off the side of a fusiform initial. C: Corylus sieboldiana. D: Carpinus coreana. Arrow indicates new ray initial originated from division off the end of a fusiform initial.
Table 1. Size variation of cambial cells in tangential sections of some Betulaceae

<table>
<thead>
<tr>
<th>Species</th>
<th>Fusiform initials (μm)</th>
<th>Ray initials</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Length</td>
<td>Tapering end wall</td>
</tr>
<tr>
<td>Alnus hirsuta</td>
<td>659.6±44.9</td>
<td>207.8±13.9</td>
</tr>
<tr>
<td>A. firma</td>
<td>608.0±49.7</td>
<td>182.3±15.7</td>
</tr>
<tr>
<td>Betula costata</td>
<td>467.8±34.3</td>
<td>150.3±13.7</td>
</tr>
<tr>
<td>B. platyphylla var. japonica</td>
<td>487.0±49.5</td>
<td>165.7±18.7</td>
</tr>
<tr>
<td>B. davurica</td>
<td>467.4±65.4</td>
<td>174.6±10.4</td>
</tr>
<tr>
<td>Corylus sieboldiana</td>
<td>409.8±40.7</td>
<td>167.2±18.5</td>
</tr>
<tr>
<td>C. heterophylla var. thumbergi</td>
<td>440.6±41.0</td>
<td>119.0±7.8</td>
</tr>
<tr>
<td>C. heterophylla</td>
<td>400.8±36.9</td>
<td>132.7±8.1</td>
</tr>
<tr>
<td>Carpinus cordata</td>
<td>435.9±40.3</td>
<td>127.0±14.2</td>
</tr>
<tr>
<td>C. laxiflora</td>
<td>347.6±57.3</td>
<td>86.3±8.8</td>
</tr>
<tr>
<td>C. coreana</td>
<td>383.2±40.1</td>
<td>91.8±7.9</td>
</tr>
</tbody>
</table>

*: Number of cell

their height and width represent the diverse variation as fusiform initials (Table 1). Though the average height of the ray initials is about 12.4 cells, the height varies from 1-34 cells in the examined species, the highest being in C. laxiflora and the lowest in B. platyphylla var. japonica. The average height of ray initials in the genus ranges from 9-15 cells in the examined genera, the lowest being in Betula and the highest in Carpinus. The width of the ray initials varies from 1-4 cells in different species. The

![Histogram represents frequency of ray initial unit of different widths in tangential sections of some Betulaceae.](image-url)
The ray initial in the tangential section constitutes 13.4-37.5%, which is the lowest(13.4%) in C. sieboldiana, medium(24-25%) in A. hirsuta and C. davurica, the highest(37.5%) in C. coreana(Fig. 4). The average number of ray initials per unit area shows 41.1-91.8 in the tangential sections, the smallest in C. sieboldiana belonging to the shrub, on the other hand, the most in C. coreana belonging to the small tree. In this way, the distribution or rate of the ray proved to be more or less in Corylus, compared with other genera. By the way, new ray initials with 1-2 cells heights are formed by cut off the side or the end of a fusiform initial(Fig. 1B, D).
FIG. 4. Histogram shows relative proportion of ray and fusiform initials in cambial zones in some Betulaceae.

Discussion

The vascular cambium, in all the species of Betulaceae studied is composed of ray and fusiform initials that make a typical non-storied arrangement. The increase of cambial circumference in relation to the secondary growth accompanied with radial oblique division in the fusiform initials in all the species of Betulaceae, which was known to occur in conifers and primitive dicotyledons (Bailey, 1923; Cumbie, 1967), likewise in more advanced *Hibiscus laciocarpus* (Cumbie, 1963) and *Acer pseudoplatanus* (Catesson, 1964). It was confirmed that the length of fusiform initials of Betulaceae, 347.6~6.59.6 μm, is shorter than that of certain dicotyledons and conifers regarded as primitive in its structure (Bailey, 1923; Bannan, 1951, 1956, 1960a, 1960b, 1962, 1963; Bannan & Bayly 1956; Ghouse & Yunus, 1974a; Ghouse & Iqbal, 1975; Ghouse et al., 1975, 1976), but longer than that of Verbenaceae (Ghouse et al., 1980) or families that have storied cambium, a phylogenetically more advanced type (Ghouse & Yunus, 1974b; Ghouse et al., 1973; Ajmal et al., 1986). In particular, *Corylus* and *Carpinus* are considered as more advanced than *Alnus* and *Betula* because they have shorter fusiform initials. This aspect coincides with results of the xylem anatomy by Hall (1962) and of taxonomic study by differences of vessel shape (Soh & Jeon, 1981). It is, therefore, considered as rather advanced in some degree than primitive, although the arrangement of the cambial initials leads to a nonstratified structure.

A comparison of average length of fusiform initials among the different species indicates that the length of fusiform initials mainly depends on the size of the pseudotransverse end walls which undergo local extension apically to varying extents.
in different species (Bannan, & Whalley, 1950; Bannan, 1956). Therefore, the greater the intrusive growth, the longer the fusiform initials. This trend is found in all the species of Betulaceae except C. heterophylla var. thunbergii. The length of fusiform initials of Betulaceae studied is 464.3 μm on the average, which is more or less differ from that of the vessel member (433.1 μm) reported in the study of Soh & Jeon (1981), while that of Tippo (1938) and Metcalfe & Chalk (1950) showed wide differences with domestic Betulaceae, reporting 730 μm, 900 μm respectively. It may be estimated that such differences are due to the gap of growing environment and annual ring of species investigated, because the precursor cells of vessel member do not undergo any change of the length in differentiational process. The diameter of vessel member and the length of fiber shows much greater size than the initials. So the precursor cells underwent changes like enlargement or intrusive growth in differentiational process. Therefore, cambial initials should be not regarded in the same light with derivative cells.

Ray initials were composed of the isodiametric cells, showed various variation in height, width, relative ratio, and distribution number per unit area in all the species of Betulaceae. The relative proportion of ray initials in tangential sections has revealed that they constitute about 13.4~37.5% of cambial zone and it was lower in Corylus belonging to shrub, but higher relatively in most tree species except C. coreana. A comparison of the relative proportion of ray and fusiform initials among different species reveals that those species which possess wider trunk have, in general, higher ratio of ray initials than the shrubs. This probably is due to the fact that wider trunks, the demand for radial translocation of water and nutrients, is far more than what is required in slender stems. Also this is assumed to be supported because of the fact that as the girth of trunk increases in Dalbergia sissoo (Ghouse & Yunus, 1973) and Prosopis spicigera (Ghouse & Iqbal, 1977), the rate of ray initials does so. However, it was certified that the rate of ray initials is maintained mostly constant all during the secondary growth in Citrus sinensis (Khan et al., 1983) and Terminalia tomentosa (Mahmooduzzafar & Iqbal, 1986). It also shows diverse variation according to the species, indicating less than 10% in Aeschynomene hispida (Butterfield, 1972) and Abies concolor (Wilson, 1963, 1964), 30~40% in Dalbergia sissoo (Ghouse & Yunus, 1973), about 28% in Polyalthia longifolia (Ghouse & Hashmi, 1980) and 75% in Dillenia indica (Ghouse & Yunus, 1974a). C. coreana which belonging to a small tree out of Betulaceae scored 35.9% much higher than Alnus and Betula that have wider trunks. Therefore, it is necessary for study of whether the rate of ray initials in each species is originated inevitably from needs of nutrients and water due to differences of the habit of the stem.

It seems that the rate of ray initials is very closely related with the frequency of occurrence of new ray initials. In Betulaceae, new ray initials are originated in the height of 1~2 cells, through the partial separation in the ends or lateral parts of fusiform initials. This aspect has been reported in Pyrus communis (Evert, 1961), Delonix regia (Ghouse & Hashmi, 1981), and Robinia pseudoacacia (Han & Soh, 1990). The frequency of occurrence in these new ray initials is known to be controlled by the extent of physical contact with the fusiform initials (Philipson et al., 1971) or by the
accumulation of the unknown stimulus (Carmi et al., 1972).

In this study, width of ray initials is exclusively uniseriate in Alnus, however, Soh & Jeon(1981) reported 1-3 cells width in Alnus. Metcalfe & Chalk(1950) and Soh & Jeon(1981) described that the aggregate rays are frequently found in the Betulaceae. But these structures are not found in the cambial zone of Betulaceae investigated in this study at all. It is considered that the aggregate ray is the products of the differentiational process. Therefore, there is a considerable difference between ray initials and rays. As mentioned above, though the structure and the activity of the cambium are reflected in the secondary xylem, it is very important to study cambium itself, because there are various differences between the meristem and derivative tissues.

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References


