Article

Wood anatomical report of Siberian species of Betula (Betulaceae)

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Abstract

The wood anatomy of six species of *Betula* from Siberia was described. These six species share typical wood anatomical characters of *Betula* in general. Two small shrubs, *B. fruticosa* subsp. *montana* and *B. nana* subsp. *rotundifolia*, are distinguished from the others in having smaller and shorter vessel elements, shorter fiber tracheids, shorter axial parenchyma strands, more numerous marginal cells of multiseriate rays. These two species consistently have shorter vessel elements, from near the pith throughout the secondary xylem to the outermost part, than a tree species, *B. microphylla*. It is discussed whether this feature is characteristic of the small shrubs of *Betula*.

Key Words: *Betula*, Siberia, wood anatomy

The genus *Betula* contains about 35 or more species of deciduous trees and shrubs, which are widely distributed in temperate and boreal zones of the Northern Hemisphere (Kubitzki, 1993). Several anatomical studies of the woods of *Betula* have been so far made on the materials from various regions and it has been found that woods of the genus are considerably uniform in the anatomical features (Metcalfe and Chalk, 1950; Hall, 1952; Miller and Cahow, 1989; Suzuki et al., 1991). Hall (1952) investigated the wood anatomy of 33 species of *Betula* and indicated that species belonging to subsection *Nanae*, which are small or dwarf shrubs of the cold circumboreal and (sub)arctic region, are different from the other species in some anatomical features such as numerous pores per square mm, small vessel diameters, and short vessel elements. According to him, the short vessel elements observed in subsection *Nanae* are probably owing to young age of the specimens.

In Siberian region, about eight species of *Betula* are distributed in lowland area to high mountains (Schemberg, 1992). Their growing habits are various such as tall trees, small trees, shrubs, or small shrubs. In a Japan–Russia cooperative botanical expedition in the Central Siberia in 1993, several wood samples of *Betula*, including small shrubs, were collected from Kudznetskiy Alatau Mts. in Khakas Republic and West Sayan Range in Tuwa Republic. Although the collected samples were too few for the comprehensive description of woods, this study was carried out because that Siberian species of *Betula* have not been investigated anatomically. Regarding the wood anatomy of *Betula* in Russia and adjacent states (the former USSR), a few studies have been done by the materials from regions near Europe (Alekseeva, 1962a, b; Barykina and Kudryashev, 1973; Tumanyan, 1975).

As an outline of the wood anatomy of *Betula* from Siberia was previously given elsewhere (Takahashi, 1995), in this paper, wood anatomy of every species collected are fully described and discussed. Moreover a special attention is given to the difference in lengths of vessel elements and fibers between small shrubs and tree species.

Materials and Methods

Anatomical investigation was made in eight wood samples from six species (Table 1). Voucher herbarium specimens will be deposited in Makino Herbarium, Tokyo Metropolitan University (MAK); University Museum, University of Tokyo (TI); Museum of Nature and Human Activities, Hyogo (HYO). Wood samples were cut off from the outermost part of erect stumps in the field, sectioned and macerated according to standard technique. The ranges and average lengths of vessel elements and fibers were measured by 50 macerated elements. The number of pores per square mm were estimated according to Wheeler (1986). In three species, i.e., *Betula fruticosa* Pallas subsp. *montana* M.Schemberg, *B. microphylla* Bunge, and *B. nana* L. subsp. *rotundifolia* (Spach) Malyschev, small pieces of woods were cut off from sample blocks at intervals of about 2 mm from pith toward the outside and the lengths of vessel elements and fiber tracheids were measured for each blocks.

Results

Descriptions of woods

Betula alba L. [Plate 1]

Wood diffuse porous. Growth rings distinct, delineated by radially flattened cells. Pores evenly distributed, many,

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Table 1. Sources of materials investigated. Tr=tree, sTr=small tree, sSh=small shrub. Asterisked specimens (*) are those on which anatomical descriptions and microscopic photographs were mainly based upon.

Science Name	Source	Spacimen No.	Habit	Height (m)	DBH (cm)
Betula alba	Khakas; Ordzhonikidzevsk Distr., Agaskir. 400 m alt., 16 July 1993.	9322409	Tr	8	20
Betula fruticosa subsp. *montana*	Tuwa; Kaa-khemsk Distr., Khandagayty. 1050 m alt., 30 July 1993.	9322433	sSh	2	2
Betula microphylla	Tuwa; Ovurskyi Distr., Khandagayty. 1300 m alt., 28 July 1993.	9322432	sTr	4	8
Betula nana subsp. *rotundifolia*	Khakas; Ordzhonikidzevsk Distr., Mt. Zaozernaya. 1350 m alt., 16 July 1993.	9322415*	sSh	0.5	2
	Tuwa; Kaa-Ahemsk Distr., Turnat Taiga Mts. 2200 m alt., 31 July 1993.	9322435	sSh	0.3	1.5
Betula pendula	Khakas; Ordzhonikidzevsk Distr., Agaskir. 400 m alt., 16 July 1993.	9322411	Tr	10	30
Betula tortuosa	Khakas; Ordzhonikidzevsk Distr., Mt. Zaozernaya. 1350 m alt., 16 July 1993.	9322416	sTr	3	4
	Khakas; Ordzhonikidzevsk Distr., Mt. Zaozernaya. 1000 m alt., 17 July 1993.	9322420*	Tr	6	12

13–34/sq. mm; solitary and in radial multiples; solitary pores 54 %; multiples consist usually of 2–4 pores. Solitary pores angular in outline, small, 40–85 (av. 62) μm and 42–128 (av. 83) μm in tangential and radial diam.; thin walled, 2–2.5 μm. Pith flecks occasionally observed.

Vessel elements medium to slightly long, 390–900 (av. 662) μm long; perforation plates exclusively scalariform with 12–25 fine bars. Intervessel pits alternate and minute, 2.5–3 μm in diam. Helical thickenings not observed.

Imperforated tracheary elements fiber tracheids; round to polygonal in outline, 8–30 μm in diam.; short to medium sized, 500–1470 (av. 939) μm long; walls 3–4 μm thick; circular bordered pits small (2–4 μm) with oblique slit-like apertures.

Axial parenchyma sparse; apotracheal diffuse, diffuse-in-aggregate, and discontinuous terminal lines of one cell wide. Strands consist of 5–8 cells, 580–780 μm high; component cells 17–25 μm wide and 60–150 μm tall in tangential section. Crystals not observed.

Rays uniseriate and multiseriate, 9–15/mm length in tangential section; nearly homogeneous consist of procumbent cells, ocassionally upright and square cells intermingled in uniseriate rays or margins of multiseriate rays. Uniseriate rays 1–14 cells, 35–340 μm high. Multiseriate rays 2–3 cells (15–25 μm) wide and 90–410 μm high, with usually 1–2, rarely up to 7, marginal cells. Procumbent cells 12–25 μm high and 42–143 μm long in radial section. Ray-vessel pits alternate and minute, similar to intervessel pits. Aggregate rays and crystals not observed.

Betula fruticosa Pallas subsp. ***montana***
M.Schemberg [Plate 2]

Wood diffuse porous. Growth rings distinct, delineated by radially flattened cells. Pores evenly distributed, with a tendency of arrangement in one row of solitary and multiple pores at the beginning of growth rings, numerous, 101–135/sq. mm; solitary, in radial multiples, and in irregular clusters; solitary pores 25 % ; multiples consist of 2–4 pores or more. Solitary pores angular in outline, minute to small, 17–53 (av. 33) μm and 25–63 (av. 43) μm in tangential and radial diam.; thin walled, 1.5–2 μm.

Vessel elements short to medium sized, 190–500 (av. 330) μm long; perforation plates exclusively scalariform with 12–24 fine bars. Intervessel pits alternate and minute, 2.5–3 μm in diam. Helical thickenings not observed.

Imperforated tracheary elements fiber tracheids; polygonal in outline, 8–20 μm in diam.; short, 260–760 (av. 483) μm long; walls 3-4 μm thick; circular bordered pits small (2–4 μm) with oblique slit-like apertures.

Axial parenchyma sparse; apotracheal diffuse, diffuse-in-aggregate, and discontinuous terminal lines of one cell wide. Strands consist of 4–6 cells, 265–415 μm high; component cells 11–18 μm wide and 60–110 μm tall in tangential section. Crystals not observed.

Rays uniseriate and multiseriate, 11–17/mm length in tangential section; nearly homogeneous consist of procumbent cells, ocassionally upright and square cells intermingled in uniseriate rays or margins of multiseriate rays. Uniseriate rays 1–13 cells, 25–250 μm high. Multiseriate rays 2–3 cells (13–23 μm) wide and 90–590 μm high, with mostly 1–6, up to 10, marginal cells. Procumbent cells 13–23 μm high and 33–60 μm long in radial section. Ray-vessel pits alternate and minute, similar to intervessel pits. Aggregate rays and crystals not observed.

Betula microphylla Bunge [Plate 3]

Wood diffuse porous. Growth rings distinct, delineated by radially flattened cells. Pores evenly distributed, numerous, 106–180/sq. mm; solitary and in radial multiples; solitary pores 30 % ; multiples consist of 2–4 pores or more. Solitary pores angular in outline, small, 23–60 (av. 43) μm and 27–68 (av. 50) μm in tangential and radial diam.; thin walled, 1.5–2 μm. Pith flecks occasionally observed.

Vessel elements medium sized, 370–770 (av. 623) μm long; perforation plates exclusively scalariform with 12–26 fine bars. Intervessel pits alternate and minute, 2.5–3 μm in diam. Helical thickenings not observed.

Imperforated tracheary elements fiber tracheids; round to polygonal in outline, 8–28 μm in diam.; slightly short, 400–1100 (av. 853) μm long; walls 2–3 μm thick; circular bordered pits small (2–4 μm) with oblique slit-like apertures.

Axial parenchyma sparse; apotracheal diffuse, diffuse-in-aggregate, and discontinuous terminal lines of one cell wide. Strands consist of 4–8 cells, 325–585 μm high; component cells 13–23 μm wide and 70–170 μm tall in tangential section. Crystals not observed.

Rays uniseriate and multiseriate, 10–14/mm length in tangential section; nearly homogeneous consist of procumbent cells, ocassionally upright and square cells intermingled in uniseriate rays or margins of multiseriate rays. Uniseriate rays 1–15 cells, 25–350 μm high. Multiseriate rays 2–4 cells (15–25 μm) wide and 110–330 μm high, with usually 1–3, rarely up to 9, marginal cells. Procumbent cells 13–25 μm high and 43–90 μm long in radial section. Ray-vessel pits alternate and minute, similar to intervessel pits. Aggregate rays and crystals not observed.

Betula nana L. subsp. ***rotundifolia*** (Spach) Malyschev [Plate 4]

Wood diffuse porous. Growth rings distinct, delineated by radially flattened cells. Pores evenly distributed, with a tendency of arrangement in one row of solitary and multiple pores at the beginning of growth rings, numerous, 82–201/sq. mm; solitary, in radial multiples, and in irregular clusters; solitary pores 27 % ; multiples consist of 2–4 pores or more. Solitary pores angular in outline, minute to small, 17–55 (av. 34) μm and 17–65 (av. 39) μm in tangential and radial diam.; thin walled, 1.5–2 μm. Pith flecks occasionally observed.

Vessel elements short to medium sized, 190–480 (av. 355) μm long; perforation plates exclusively scalariform with 8–20 fine bars. Intervessel pits alternate and minute, 2.5–3 μm in diam. Helical thickenings not observed.

Imperforated tracheary elements fiber tracheids; polygonal in outline, 8–20 μm in diam.; short, 300–770 (av. 533) μm long; walls 1.5–2.5 μm thick; circular bordered pits small (2–4 μm) with oblique slit-like apertures.

Axial parenchyma sparse; apotracheal diffuse, diffuse-in-aggregate, and discontinuous terminal lines of one cell wide. Strands consist of 2–5 cells, 225–415 μm high; component cells 12–20 μm wide and 55–105 μm tall in tangential section. Crystals not observed.

Rays uniseriate and multiseriate, 13–18/mm length in tangential section; nearly homogeneous consist of procumbent cells, ocassionally upright and square cells intermingled in uniseriate rays or margins of multiseriate rays. Uniseriate rays 1–14 cells, 30–300 μm high. Multiseriate rays 2–3 cells (15–20 μm) wide and 70–310 μm high, with mostly 1–6, up to 9, marginal cells. Procumbent cells 12–23 μm high and 28–48 μm long in radial section. Ray-vessel pits alternate and minute, similar to intervessel pits. Aggregate rays and crystals not observed.

Betula pendula Roth [Plate 5]

Wood diffuse porous. Growth rings distinct, delineated by radially flattened cells. Pores evenly distributed, numerous, 83–117/sq. mm; solitary and in radial multiples; solitary pores 26 % ; multiples consist of 2–4 pores or more. Solitary pores angular in outline, small, 33–88 (av. 56) μm and 35–128 (av. 79) μm in tangential and radial diam.; thin walled, 2–2.5 μm. Pith flecks occasionally observed.

Vessel elements medium to slightly long, 470–1150 (av. 913) μm long; perforation plates exclusively scalariform with 16–28 fine bars. Intervessel pits alternate and minute, 2.5–3 μm in diam. Helical thickenings not observed.

Imperforated tracheary elements fiber tracheids; round to polygonal in outline, 8–35 μm in diam.; short to medium sized, 610–1600 (av. 1191) μm long; walls 2.5–5 μm thick; circular bordered pits small (2–5 μm) with oblique slit-like apertures.

Axial parenchyma sparse; apotracheal diffuse, diffuse-in-aggregate, and discontinuous terminal lines of one cell wide. Strands consist of 6–8 cells, 730–1130 μm high; component cells 22–32 μm wide and 80–206 μm tall in tangential section. Crystals not observed.

Rays uniseriate and multiseriate, 8–14/mm length in tangential section; nearly homogeneous consist of procumbent cells, ocassionally upright and square cells intermingled in uniseriate rays or margins of multiseriate rays. Uniseriate rays 1–16 cells, 45–340 μm high. Multiseriate rays 2–4 cells (22–35 μm) wide and 150–570 μm high, with usually 1–2, rarely up to 12, marginal cells. Procumbent cells 17–25 μm high and 45–105 μm long in radial section. Ray-vessel pits alternate and minute, similar to intervessel pits. Aggregate rays and crystals not observed.

Betula tortuosa Ledeb. [Plate 6]

Wood diffuse porous. Growth rings distinct, delineated by radially flattened cells. Pores evenly distributed, many to numerous, 49–82/sq. mm; solitary and in radial multiples; solitary pores 30 % ; multiples consist of 2–4 pores or more. Solitary pores angular in outline, small, 40–88 (av. 59) μm and 42–103 (av. 74) μm in tangential and radial diam.; thin

walled, 1.5–2 μm. Pith flecks occasionally observed.

Vessel elements medium sized, 420–880 (av. 661) μm long; perforation plates exclusively scalariform with 15–30 fine bars. Intervessel pits alternate and minute, 2.5–3 μm in diam. Helical thickenings not observed.

Imperforated tracheary elements fiber tracheids; round to polygonal in outline, 8–30 μm in diam.; short to medium sized, 580–1270 (av. 946) μm long; walls 2–4 μm thick; circular bordered pits small (2–4 μm) with oblique slit-like apertures.

Axial parenchyma sparse; apotracheal diffuse, diffuse-in-aggregate, and discontinuous terminal lines of one cell wide. Strands consist of 6–8 cells, 650–870 μm high; component cells 20–25 μm wide and 65–160 μm tall in tangential section. Crystals not observed.

Rays uniseriate and multiseriate, 9–13/mm length in tangential section; nearly homogeneous consist of procumbent cells, ocassionally upright and square cells intermingled in uniseriate rays or margins of multiseriate rays. Uniseriate rays 1–15 cells, 30–300 μm high. Multiseriate rays 2–3 cells (18–35 μm) wide and 100–600 μm high, with usually 1–2, rarely up to 9, marginal cells. Procumbent cells 20–33 μm high and 40–128 μm long in radial section. Ray-vessel pits alternate and minute, similar to intervessel pits. Aggregate rays and crystals not observed.

Change in element length from pith to outside

Changes in lengths of vessel elements and fiber tracheids from pith to outside were measured in 3 species, *B. fruticosa* subsp. *montana*, *B. microphylla* and *B. nana* subsp. *rotundifolia* (Fig. 1). In *B. microphylla*, average lengths of vessel elements and fiber tracheids at the nearest pith are 353 μm and 502 μm, respectively, and they become longer toward the outside until 623 μm and 853 μm in outermost part of the stem. On the other hand, average lengths of both elements are clearly short in the other two species. In *B. fruticosa* subsp. *montana*, those of vessel elements and fiber tracheids at the nearest pith are 257 μm and 349 μm and in *B. nana* subsp. *rotundifolia* 234 μm and 328 μm, respectively. And then, they gradually become longer toward the outside until 330 μm and 483 μm in the former and 355 μm and 533 μm in the latter, respectively. Increase in the element length from pith to outside is not so conspicuous in these two species as in *B. microphylla*.

Discussion

It was found that six species of *Betula* from Siberia share wood features such as diffuse-porosity, small and angular vessels, scalariform perforation plates with, mostly, many fine bars, dense and minute alternate intervessel pits, lack of libriform wood fibers, apotracheal wood parenchyma, and homogeneous rays. These features are characteristic of the genus in general (Metcalfe and Chalk, 1950; Hall, 1952).

Among the six species, three of tree species, *B. alba, B. pendula*, and *B. tortuosa*, are very similar to each other in the wood anatomy except for number of pores per square mm and percentage of solitary pores.

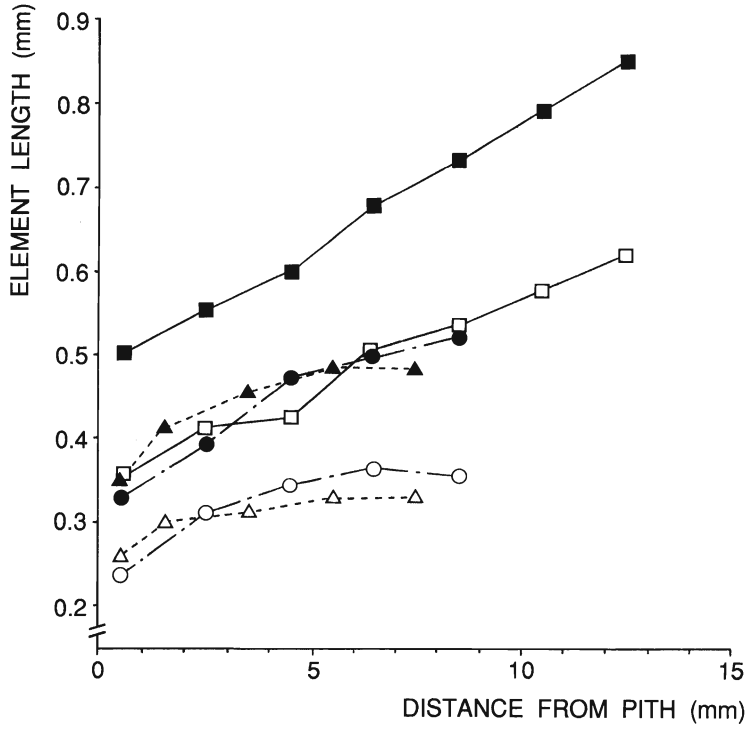

Fig. 1. Changes in element lengths from pith to outside. Squares; *Betula microphylla*, Triangles; *Betula fruticosa* subsp. *montana*, Circles; *Betula nana* subsp. *rotundifolia*. In each species, solid marks indicate average lengths of fiber tracheids and open marks those of vessel elements.

B. microphylla also has similar wood features to the above, but pore diameters are smaller and the vessel elements and fiber tracheids are slightly shorter. This is probably because the wood sample of the species investigated was cut off from thin stump of an immature tree. Unfortunately no wood sample from thick stump of bigger plant could be collected in the field.

Two species of small shrub, *B. fruticosa* subsp. *montana* and *B. nana* subsp. *rotundifolia*, both are belonging to subsection *Nanae*, are distinguished from the others in having smaller and shorter vessel elements, shorter fiber tracheids, shorter axial parenchyma strands, more numerous marginal cells of multiseriate rays, some of them are the characteristic of subsection *Nanae* as indicated by Hall (1952). Furthermore the latter species is peculiar in also having fewer bars in scalariform perforation plates, fewer component cells of axial parenchyma strands, and more rays per mm length in tangential section. Similar features are also observed in woods of *B. nana* grown in other northern countries such as Greenland (Miller, 1975) and Finland (Bhat and Karkkainen, 1982).

Those two species were also found to consistently have shorter vessel elements and fiber tracheids throughout the secondary xylem, from the vicinity of the pith to the outermost part, than a tree species *B. microphylla*. According to Hall (1952), the short vessel elements observed in small shrubs of subsection *Nanae* are probably owing to young age of the specimens, in which the fusiform initials have not yet reached their mature length. As considering the growing habit of these small shrubs in the field, it is not likely that they obtain the same element length as *B. pendula* or *B. alba* has. However, additional investigations are necessary in more mature wood samples to examine whether the element length of small shrubs of *Betula* is originally short or not.

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