WOOD IDENTIFICATION OF COMMERCIALLY IMPORTANT NORTH AMERICAN SPECIES OF BIRCH (BETULA)

by

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Summary

The wood anatomy was studied of the four commercially important North American species of birch: *Betula alleghaniensis*, *B. lenta*, *B. nigra*, and *B. papyrifera*. Although the wood from these species is fairly homogeneous, it appears that *B. papyrifera* can be separated from *B. nigra; B. alleghaniensis* and *B. lenta*, though indistinguishable from each other, can be separated from both *B. papyrifera* and *B. nigra*. The diagnostic features are as follows: ray width, ray cell and ray cell shape as viewed on the tangential longitudinal section, average number of bars per perforation plate, and contents of axial parenchyma cells. In addition to these species, two commercially important European species (*B. pendula* and *B. pubescens*) and two additional North American tree species (*B. occidentalis* and *B. populifolia*) were studied. A dichotomous key to all eight species is presented.

Key words: Wood anatomy, wood identification, *Betula*, birch, Betulaceae.

Introduction

In the forest products industry and in other identification situations, it is often desirable to distinguish between species, especially the commercially important ones. Wood anatomists have not previously demonstrated methods for the reliable separation of the birches. Hall (1952) studied the wood of 33 species of *Betula* L., but offered no means for their separation. A year later, Stark (1953) published a key to the woods of six North American tree species of birch using number of bars per perforation plate, vessel element and fibre lengths, heartwood colour, and density as distinguishing features. This key, however, was not incorporated into textbooks or later cited by authors. Panshin and De Zeeuw (1970, 1980) and Panchin *et al.* (1964) grouped five North American tree species of birch and made no mention of diagnostic features for species separation. Core *et al.* (1976, 1979) stated ‘the various birches cannot be separated.’ To determine if reliable diagnostic features are present to separate species or species groups, we studied the wood anatomy of the following four commercially important North American species of birch: yellow birch, *B. alleghaniensis* Britton (= *B. lutea* Michx. f.); sweet birch, *B. lenta* L.; river birch, *B. nigra* L.; and paper birch, *B. papyrifera* Marsh. For comparison, we examined the two commercially important European birches, *B. pendula* Roth (= *B. verrucosa* Ehrh.) and *B. pubescens* Ehrh., and two additional North American tree species, e.g. water birch, *B. occidentalis* Hook. (= *B. fontinalis* Sarg.) and gray birch, *B. populifolia* Marsh. Virginia roundleaf birch [*B. uber* (Ashe) Fern.], the only other North American tree species of *Betula*, was not examined, because it is extremely rare and specimens were not available.

There is some disagreement as to which North American species of *Betula* are commercially important. Brisbin and Sonderman (1973) state that *B. alleghaniensis*, *B. lenta*, and *B. papyrifera* are of primary significance and *B. nigra* and *B. populifolia* are secondary. Core *et al.* (1976, 1979) limit discussion to *B. alleghaniensis* and *B. nigra*; whereas Panshin and De Zeeuw (1970, 1980) and Panshin *et al.* (1964) include *B. alleghaniensis*, *B. lenta*, *B. nigra*, *B. papyrifera*, and *B. populifolia*. We followed Brisbin and Son-
derman (1973) and selected _B. alleghaniensis_, _B. lenta_, and _B. papyrifera_ as the commercially important species. We included _B. nigra_ because Panshin and De Zeeuw (1980) and Core et al. (1979) also included this species. Of the three other North American tree species, we excluded _B. uber_, _B. occidentalis_, and _B. populifolia_ as commercially important because of their limited range, size, and availability.

The properties and economic uses of _B. alleghaniensis_ and _B. lenta_ are similar (Panshin & De Zeeuw 1980; USDA Forest Service 1987), and these species are often mixed in the trade. Although these two species are relatively difficult to work with hand tools, they can be easily machined. However, they must be dried carefully to prevent checking and warping. _Betula alleghaniensis_ is among the principal furniture woods of the United States (Brisbin & Sonderman 1973). _Betula papyrifera_ and _B. nigra_ are lighter and rank considerably below _B. alleghaniensis_ and _B. lenta_ in strength, stiffness, and hardness. They are relatively easy to dry and to work with hand tools. Both species are used for pulp, fuel wood, and small crafts, and _B. papyrifera_ is desirable for tooth picks, tongue depressors, and coffee stirrers because of its machineability, nearly white colour, and the fact that it does not impart a colour, odour, or taste.

_Betula alleghaniensis_ and _B. lenta_ are mesic forest species native to the Appalachian region. _Betula alleghaniensis_, however, is more northern and extends into the Lake States and Canada. It occurs along the Appalachian Mountains as far as northern Georgia, and to the north grows east to the Maritimes and west to Minnesota. _Betula lenta_ grows as far south as Alabama and as far north as Maine. It is bounded in the west by the Ohio Valley and Lake Erie. _Betula nigra_ is a southern lowland species, and it occurs in the southeastern United States. It grows to the Atlantic Ocean in the east and to Missouri, eastern Oklahoma, and eastern Texas in the west. It extends north to New Jersey, Ohio, and Iowa and occurs locally in Wisconsin, New York, and New Hampshire. _Betula papyrifera_ is a northern boreal species, growing east to the Maritime Provinces of Canada and west to Alaska. It extends south to Pennsylvania, Wisconsin, and into Idaho. It will occur as far north as Hudson’s Bay in the east and into the Northwest Territories in the west (Little 1971).

Following the classification of Rehder (1949), the six North American tree species of _Betula alleghaniensis_, _B. lenta_, and _B. nigra_ are placed within subsection Costatae; whereas, _B. papyrifera_, _B. occidentalis_, and _B. populifolia_ are assigned to subsection _Albae_. Hall (1952) reports that subsections _Costatae_ and _Albae_ are very closely allied, with the _Costatae_ most likely the more advanced of the two.

**Materials and Methods**

For each of the four commercially important North American species, 10 or 11 wood samples were selected from the MADw* wood collection. The samples examined are listed below by species. Specimens are cited by species, collector, collector’s number, and xylarium designation in parentheses. Unvouchedered specimens are cited only by xylarium designation in parentheses.

_Betula alleghaniensis_: W.E. McQuilken, BWCw 8666 (MADw 767); H.P. Brown, BWCw 8002 (MADw 8723); F. Schmidt (MADw 10162); Watkins, USw 2230 (MADw 19910); W.E. Johns (MADw 23625); H.H. Smith, F 72208 (MADw 27319); H.H. Smith, F 72202 (MADw 27320); H.H. Smith, F 72210 (MADw 27321); A. Okkonen 1 (MADw 40885); A. Okkonen 2 (MADw 40886). - _B. lenta_: Ostronder (MADw 944); (MADw 6179); A. Koehler (MADw 6466); (MADw 6698); H.S. Newins, BWCw 8046 (MADw 8765); D.A. Kribs, BWCw 8172 (MADw 8912); Northeastern For. Exp. Stat., (MADw 23594); US Bureau Forestry, F 01690 (MADw 27316); H.H. Smith, F 72198 (MADw 27317); H.H. Smith, F 7220 (MADw 27318). - _B. nigra_: Allegheny For. Exp. Stat., BWCw 8602 (MADw 825); Allegheny For. Exp. Stat., BWCw 8601

* MADw and SJRw are acronyms for the wood collection at the Forest Products Laboratory, Madison, Wisconsin, U.S.A.
For each of the other species, we surveyed available slides and selected additional specimens from the MADw and SJRw wood collections, but in no case did we examine more than seven specimens per species.

We cut sectioning blocks and samples for maceration from the outer portion of the sapwood whenever possible to obtain mature trunk wood. Standard microtechnique practices were followed.

Observations and measurements follow the procedures described by Miller (1981) with the exception of vessels per square millimetre, the number of bars per perforation plate, and the reporting of some quantitative values. For vessels per square millimetre, each vessel or opening is counted as a single unit (Wheeler 1986). For vessel and fibre lengths, vessel diameters, and ray heights, the range reported is the range of specimen averages.

Results

The description follows the IAWA Standard List of Characters (IAWA Committee 1981; Miller 1981) and is based on the examination of *B. alleghaniensis*, *B. lenta*, *B. nigra*, and *B. papyrifera*. Characters not specifically mentioned are negative. Quantitative characters are ranges of averages. Table 1 lists the ranges of averaged for vessel diameters, vessels per square millimetre, ray height, vessel element length, and fibre length. Table 2 lists the diagnostic characters for identification. The Appendix is a dichotomous key including the four described species, the two commercially important European species (*B. pendula* and *B. pubescens*), and the two additional North American tree species (*B. occidentalis* and *B. populifolia*).

General features — Heartwood off-white to brown, occasionally with slight reddish tinge; not fluorescent under longwave (365 nm) ultraviolet light. Pith flecks occasionally present in some specimens. Specific gravity (ovendry weight/green volume) 0.55 in *B. alleghaniensis*, 0.60 in *B. lenta*, 0.48 in *B. papyrifera* (USDA Forest Service 1987), and 0.49 in *B. nigra* (Lutz 1972).

Microscopic features — Growth rings distinct. Vessels diffuse, solitary, and in short radial multiples of 2-3; 19–58/mm², most-

Table 1. Range of averages for vessel diameter, vessels per square millimetre, ray height, vessel element length, and fibre length.

<table>
<thead>
<tr>
<th>Species of <em>Betula</em></th>
<th>Vessel diameter (μm)</th>
<th>Vessels per mm²</th>
<th>Ray height (μm)</th>
<th>Vessel element length (μm)</th>
<th>Fibre length (μm)</th>
</tr>
</thead>
</table>
Table 2. Useful characteristics for the identification of the commercially important North American species of Betula.

<table>
<thead>
<tr>
<th>Species of Betula</th>
<th>Bars per perforation plate 1 (number)</th>
<th>Ray width (cells)</th>
<th>Ray and ray cell shape 2</th>
<th>Axial parenchyma cell contents 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>B. alleghaniensis</td>
<td>11–20</td>
<td>3–4</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>B. lenta</td>
<td>11–19</td>
<td>3–4</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>B. nigra</td>
<td>6–10</td>
<td>3–4</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>B. papyrifera</td>
<td>15–25</td>
<td>2–3</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

1) Number of bars per perforation plate reported as range of averages calculated from 25 measurements per sample.
2) Ray and ray cell shape as viewed on the TLS: + is fusiform ray shape; circular ray cell shape; – is laterally flattened ray and ray cell shape.
3) Axial parenchyma cell contents are determined from unstained sections: + is russet (reddish brown or yellowish brown) contents; – is colourless or no contents.

ly round; average diameters 54–102 µm, average vessel element length 503–1096 µm (Table 1). Perforation plates exclusively scalariform; on average 6–10 bars in B. nigra (Fig. 2), 10–20 bars in B. alleghaniensis and B. lenta, and 15–26 bars in B. papyrifera (Fig. 3; Table 2). Spiral thickenings absent; although intervacular pit apertures occasionally coalescent sometimes giving the impression of helical sculpturing. Tyloses absent. Intervascular pitting alternate; mostly 4 µm, occasionally 3 or 5 µm; vessel-ray pitting same as intervacular pitting; not vestured. Fibres nonseptate, although structures resem-}

Fig. 1. Scatter plot showing the average number of bars per perforation plate and the average ray width in cells. A = Betula alleghaniensis; L = B. lenta; N = B. nigra; P = B. papyrifera.
Figs. 2 & 3. Radial sections showing number of bars per scalariform perforation plate; × 200. - 2: *Betula nigra* showing 11 bars/plate on the left and 8 bars/plate on the right. - 3: *B. papyrifera* showing 21 bars/plate on the left and 19 bars/plate on the right.

2). In *B. papyrifera*, rays 2–3, rarely to 4, cells wide; in TLS ray and ray cell shape laterally flattened (Figs. 6, 7; Table 2). Aporatracheal parenchyma marginal and diffuse, scanty to frequent; paratracheal parenchyma absent; cell contents as viewed in unstained sections russet (reddish brown or yellowish brown) in *B. alleghaniensis*, *B. lenta*, and *B. nigra* (Fig. 8); colourless or without contents in *B. papyrifera* (Fig. 9; Table 2). Prismatic crystals absent. One druse in one sample of *B. nigra* (MADw 8902).

**Discussion**

The wood anatomy of all species of *Betula* is relatively homogeneous (Hall 1952). Panshin et al. (1964), Panshin and De Zeeuw (1970, 1980), and Core et al. (1976, 1979) reported no diagnostic differences among the commercially important North American species. Stark (1953), however, studied the native tree species of the United States and published a key that we question.

In his first couplet, Stark (1953) separates *B. nigra* from the other species on the basis

Figs. 4-7. Tangential sections showing ray width, ray shape, and ray cell shape. - 4: *Betula lenta* showing rays 3–4 cells wide and the typical fusiform ray shape; × 130. - 5: Ray from 4 at × 500 showing circular ray cell shape. - 6 *B. papyrifera* showing rays 2–3 cells wide and the laterally flattened ray shape; × 130. - 7: Ray from 6 at × 500 showing laterally flattened ray cell shape.
of the maximum number of bars per perforation plate: 10–18 in *B. nigra* and 18–38 in the other species. We found that the average number of bars per perforation plate is 6–10 and diagnostic for *B. nigra* (Fig. 2, Table 2, Appendix), but we used an average of 25 arbitrarily selected plates instead of the maximum. After examining our maximum number of bars for each species, we found that three specimens of *B. nigra* have maximums higher than 18 bars, and four specimens of *B. alleghaniensis* and *B. lenta* have maximums lower than 18 bars. There were also two specimens of *B. alleghaniensis* and *B. lenta* and two specimens of *B. nigra* with 18 bars as a maximum. All 10 specimens of *B. papyrifera* had more than 18 bars as a maximum. We also examined the maximum to see if a break occurred at some number other than 18 bars. In each case, the maximums overlapped sufficiently to negate any diagnostic value, although definite trends were evident.

In his second couplet, Stark (1953) uses both vessel element and fibre length as diagnostic features. Our data indicate that a separation based on these characters is not reliable. If we apply our data to his second couplet, we obtain a 33-percent error. Note that Stark (1953) distinguishes *B. fontinalis* from *B. papyrifera* var. *occidentalis* and that Little (1971) lists these as synonyms of *B. occidentalis*.

Figure 1 is a scatter plot showing the average number of bars per perforation plate and the ray width in cells of four of the *Betula* species. Within the limits of biological variability, we recognise neighbourhoods in which species tend to cluster. *Betula nigra* occupies the upper left corner of the range.
with wide rays and few bars. This clustering is relatively tight, and the highest value we obtained for average number of bars is 10.5, which is relatively close to one specimen of *B. alleghaniensis* (10.8) and one specimen of *B. lenta* (10.8). Thus, Figure 1 indicates that the average number of bars is a diagnostic feature for separating *B. nigra* from the other three species. *Betula lenta* and *B. alleghaniensis* cluster in the middle of the range. Within their range, we observe that *B. lenta* tends toward fewer bars and wider rays. The trend, however, is not strong enough to permit a positive identification. *Betula papyrifera* tends toward the bottom right corner, implying a high number of bars with narrow rays. One specimen of *B. papyrifera* fills within the *B. alleghaniensis* and *B. lenta* cluster. This suggests that the number of bars and ray width may not be sufficient to separate these taxa.

*Betula papyrifera* is distinguished from *B. alleghaniensis* and *B. lenta* using a combination of four characters (Table 2, Appendix). As previously noted, *B. papyrifera* most often has more bars per perforation plate than *B. alleghaniensis* and *B. lenta* (Table 2, Fig. 3), but this feature by itself is not sufficient to accurately separate the species.

As shown in Figure 1 and Table 2, *B. papyrifera* has slightly narrower rays than the other species. In *B. papyrifera*, the rays are mostly two to three cells wide at the widest point (Figs. 6, 7). In our 10 specimens, we found 3 specimens with rays four cells wide, but in each specimen fewer than three rays four cells wide were observed. This is based on surveying the entire section (five measurements in five fields) and selecting only the widest rays at the widest point. Rays of *B. alleghaniensis* and *B. lenta* are three to four cells wide (Figs. 4, 5). In our 20 specimens, we observed only 1 specimen where we could not find at least one ray that was four cells wide.

The third differentiating character is axial parenchyma cell contents. In *B. papyrifera*, the axial parenchyma cells are without contents or the contents are colourless (Fig. 9). In contrast, *B. alleghaniensis* and *B. lenta* have russet (reddish brown or yellowish brown) contents (Fig. 8).

The shape of the rays and ray cells as viewed on the tangential longitudinal section is also diagnostic. In *B. papyrifera*, the rays and ray cells appear laterally flattened (Figs. 6, 7), and in *B. alleghaniensis* and *B. lenta*, the rays are typically fusiform and the ray cells circular (Figs. 4, 5). Any of these four features is not sufficiently diagnostic to accurately separate *B. papyrifera* from *B. alleghaniensis* and *B. lenta*, but all four used in combination are diagnostic.

To determine whether or not the average number of bars per perforation plate is more diagnostic than a biased average of 10 plates with the highest number of bars, we examined the data and performed t-tests. We performed two-sided t-tests on each pair-wise combination of species for the averages of all 25 plates and repeated this for the biased averages of 10 plates with the highest number of bars. In virtually every case, a higher resolution of the differences between species was gained by using the average of all 25 plates, indicating that the overall average of 25 plates is more diagnostic than the biased average of 10 plates with the highest number of bars.

We examined six specimens of *B. occidentalis* and seven specimens of *B. populifolia*, two additional tree species in North America (Little 1971), to determine if their wood anatomy is similar to the commercial species. *Betula occidentalis* is very similar to *B. papyrifera* and both are in the subsection Albae. In fact, *B. occidentalis* was once considered a variety of *B. papyrifera* (Little 1971). It is not surprising then that we could not find any character that would separate the two. In five of the six specimens, the rays and ray cells are laterally flattened; the rays 2-3 cells wide; the axial parenchyma cell contents mostly colourless or absent; and the average number of bars per perforation plate ranges from 14 to 21. One specimen collected without herbarium material in Mt. Shasta National Park in California, however, has all the characteristics of *B. alleghaniensis* and *B. lenta*, i.e., copious coloured axial parenchyma cell contents, rays 3-4 cells wide, circular ray cells, and rays with a fusiform shape on the TLS. Perhaps this specimen is misidentified, but *B. occidentalis* is the only tree species
native to California. As unlikely as it may seem, this specimen may represent an extreme in variability. Without additional specimens and closer scrutiny, we cannot explain this apparent deviation from the norm.

*Betula populifolia* appears most like *B. alleghaniensis* and *B. lenta*, but sometimes it has characteristics of other species. The rays are usually 3-4 (occasionally 2-3) cells wide, but the shape of the rays and ray cells vary from laterally flattened to fusiform shaped rays and circular ray cells. The average number of bars per perforation plate ranges from 15 to 24 which is suggestive of *B. papyrifera*; however, the axial parenchyma cell contents vary from russet to absent. Although this species was possibly of some historical importance in northeastern United States, it is currently used primarily for firewood and pulpwood and even that does not command much of the total market. *Betula populifolia* is a highly variable species; therefore, we group it with *B. papyrifera*, *B. alleghaniensis*, *B. lenta*, and with the commercially important European species in our key (Appendix).

In Europe, the commercially important birches are limited to *B. pendula* and *B. pubescens*. According to Rehder (1949), these species are included with *B. papyrifera* in subsection *Albae*. Bhat and Karkkainen (1980) suggest a character that might separate these two woods. They argue that the average number of bars per perforation plate is indicative of species; *B. pendula* averaging less than 17.6 bars and those of *B. pubescens* averaging more than 17.6 bars. Although our results support this trend, they did not reveal a discontinuity sufficient for identification. We measured the number of bars on 25 perforation plates for three specimens of *B. pubescens* and four of *B. pendula* that yielded the following range of averages: 10–16 for *B. pendula*; 16–21 for *B. pubescens*. The breakpoint of 16 is sufficiently different from 17.6 to raise doubts about separation of the European birches using this character.

As a group, *B. pendula* and *B. pubescens* possess a combination of characters that segregate them from the commercially important North American birches. *Betula pendula* and *B. pubescens* have rays 3–4 cells wide, and the shape of the rays and ray cells are fusiform and circular, respectively. The number of bars per perforation plate varies from 10 to 21 and that overlaps the range of averages for *B. alleghaniensis*, *B. lenta*, and *B. nigra*; however, the axial parenchyma cell contents are absent or colourless. Therefore, we can separate *B. pendula* and *B. pubescens* from *B. papyrifera* on the basis of ray width and from *B. alleghaniensis*, *B. lenta*, and *B. nigra* on the basis of axial parenchyma cell contents (Appendix).

In conclusion, of the four commercially important species of North America, *B. nigra* and *B. papyrifera* can be identified from each other and from the two indistinguishable species, *B. alleghaniensis* and *B. lenta*. Characters used for these identifications include a combination of ray width, ray and ray cell shape, average number of bars per perforation plate, and the axial parenchyma cell contents. In addition, the commercially important European species, *B. pendula* and *B. pubescens*, can be separated from the four North American species using the same combination of characters. Two additional North American tree species, *B. occidentalis* and *B. populifolia*, are not distinct. *Betula occidentalis* cannot be separated from its close relative *B. papyrifera*, and *B. populifolia* is quite variable and overlaps the anatomies of *B. alleghaniensis*, *B. lenta*, *B. papyrifera*, *B. pendula*, and *B. pubescens*.

References


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Appendix: Dichotomous key to birches

The following dichotomous key includes four commercially important North American species (Betula alleghaniensis, B. lenta, B. nigra, and B. papyrifera), two commercially important European species (B. pendula and B. pubescens), and two additional North American species (B. occidentalis and B. populifolia). The commercial North American species are in bold type, whereas the European and two additional North American species are in parentheses. It is important to emphasise the importance of using macerations to obtain accurate counts for bars per perforation plate and determining averages based on a sampling of 25 plates. The key is intended for use with reference specimens to aid in the interpretation of character states.

1. Rays 2–3 cells wide; shape of rays and ray cells (TLS) laterally flattened; axial parenchyma cells without russet (reddish brown or yellowish brown) contents; average number of bars per perforation plates greater than 15 .......................... Betula papyrifera

B. occidentalis
B. populifolia

1. Rays 3–4 cells wide; shape of rays (TLS) fusiform and shape of ray cells generally circular; axial parenchyma cells with or without russet (reddish brown or yellowish brown) contents; average number of bars per perforation plates generally 6–22 .......................... 2

2. Average number of bars per perforation plate 6–10 .......................... Betula nigra

2. Average number of bars per perforation plate 10–20 .......................... 3

3. Axial parenchyma cells with russet (reddish brown or yellowish brown) contents

Betula alleghaniensis
B. lenta
B. populifolia

3. Axial parenchyma cells without russet (reddish brown or yellowish brown) contents

Betula pendula
B. pubescens
B. populifolia