Some Physical Features Associated with Pliability of Wood

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Many books and papers have been written on mechanical properties of wood, and elaborate equipment in testing laboratories, where accurate mathematical calculations are made of physical and mechanical properties of wood, speak of extensive investigations of this factor because of great economic importance of such knowledge. Wood plays a major part in civilized life as material used for all sorts of implements, furniture, building, and construction work, where mechanical properties determine the fitness of a specific wood for a particular use.

The present investigation was not prompted by any economic motive but simply by the scientific curiosity as to whether or not pliability of wood was entirely a feature associated with the chemical nature of the walls of the fibers, or whether it was also linked to external physical features of the fiber, i.e., thickness of wall, arrangement of fibers within the xylem, length of fiber, etc.

Procedure

The terms *stiffness* and *flexibility* used by wood technologists come nearest defining the meaning of pliability as used in the present paper. Garratt (3) defines these terms thus: "Stiffness is the property by means of which a body acted upon by external forces tends to retain its natural size and shape, or resists deformation. Thus a material that is difficult to bend or otherwise to deform is stiff. In contrast to this, a material that has the capacity to bend a great deal without breaking is said to be flexible. Flexibility is not the exact counterpart of stiffness, however, as it also involves toughness and pliability."

Four woody species were examined, viz., *Dirca palustris* L., *Salix nigra* Marsh, *Fagus grandifolia* Ehrh., and *Carpinus caroliniana*, Walt.

On empirical observation one could readily classify the species as representatives of three degrees of pliability. The marked difference in this respect promised a marked difference in physical characteristics causing such property.

The stems examined were approximately of the same age, i.e., nine to eleven years old. In cross section, thickness of cell wall and width of lumina in the fiber cells were measured. Since measurement from edge of lumen to middle lamella was difficult to make, measurement was made from lumen to lumen, involving, thus, always a measurement of a double wall. One hundred measurements were made in each instance, being divided between areas near the pith, half way between pith and cambium, and near the cambium. Fibers measured were approximately equally divided between spring and summer wood.

In tangential section, measurements were made of length and width of fibers, and number of cells constituting the xylem rays were counted. Observations were also made on uniformity of cell arrangement, grouping of fibers, and characteristics of the xylem rays.

Discussion

The study indicates in general that pliability of wood is associated with marked external physical features of the fibers, i.e., length of fiber and thickness of wall and lumen. Dirca has the thinnest walls, and the largest lumina of the four species examined. It is also the most pliable of these woods. Fagus as the other extreme, has the thickest fiber walls and smallest lumina. Salix and Carpinus are intermediate between these two as to thickness of cell wall, but Salix has wider lumina than Carpinus (Table I).

There is little difference between Fagus and Carpinus in the total thickness of the fibers, but Fagus has 100% more wall in a unit area than Carpinus. Comparing percentage of wall and total thickness of fiber, we again have a progressive increase in wall thickness from Dirca to Fagus, viz. Dirca 18%, Salix 30%, Carpinus 32%, and Fagus 64% (Table I).

TABLE I. MEASUREMENT AND COMPARISONS OF WOOD FIBERS FROM CROSS SECTIONS. MEASUREMENTS IN MICRONS

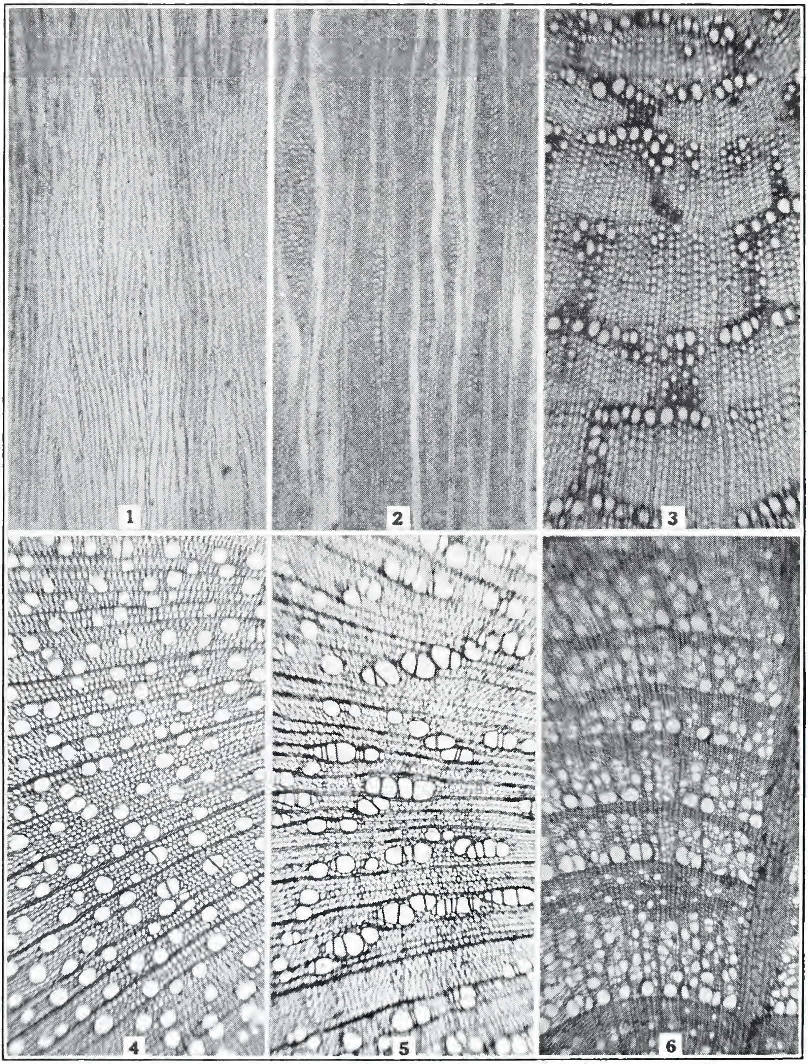
Species	Thickness of Wall	Width of Lumen	Total Thickness of Fiber	Percentage Wall of Total Thickness
Dirca palustris	2.949	13.345	16.294	18
Salix nigra	3.791	8.908	12.699	30
Carpinus caroliniana	3.349	7.22	10.569	32
Fagus grandifolia	6.409	3.646	10.055	64

We realize that thickness of wall *per se* would not necessarily mean greater rigidity in a stem, for the chemical nature of the cell wall could easily be the determining factor in rigidity. This was shown by Dadswell and Hawley (I) who found a slightly higher lignin content and slightly lower cellulose content in wood from brash oak than in tough wood from the same species. However, the uniform increase in thickness of fiber wall associated with progressively greater rigidity of stem would, seemingly, justify the conclusion that thickness of fiber wall is one of the prime factors associated with rigidity of wood.

Length of fiber correlated with pliability in wood was the opposite of what was anticipated, for the most pliable wood had the shortest fibers (Table II). However, there was a progressive increase in length from the most pliable to the most rigid wood: Dirca 161.11μ, Salix 353.36μ, Fagus 454.49μ, Carpinus 494.88μ. Probably the shorter fibers may permit a more ready bending, while the long, thick-walled fibers of Fagus and Carpinus may add rigidity to the whole stem.

The xylem rays of Dirca are usually uniseriate or biseriate (Fig. 1); Salix has mostly uniseriate rays, Carpinus has uniseriate or biseriate rays, but they are more numerous than in either Dirca or Salix; Fagus has bulky rays, up to eight cells in width (Fig. 2). Some of these rays are divided by fibers which would make them a sort of aggregate ray. One could also classify them as compound rays or very large multiseriate rays frequently found in oaks, as described by Eames and McDaniels (2, p. 177).

The pattern of the vessels is strikingly different in the four woods.



Figs. 1-6. Fig. 1. Tangential section of wood of Dirca. Fig. 2. Same of Fagus. Fig. 3. Transverse section of wood of Dirca. Fig. 4. Salix. Fig. 5. Carpinus. Fig. 6. Fagus.

TABLE II. LENGTH OF WOOD FIBER AND WIDTH OF XYLEM RAYS IN TANGENTIAL SECTION. MEASUREMENTS IN MICRONS

Species	Length of Fiber	Width of Xylem Ray
Dirca palustris	161.11	237.35
Salix nigra	353.365	275.57
Carpinus caroliniana	494.886	270.93
Fagus grandifolia	454.498	451.87

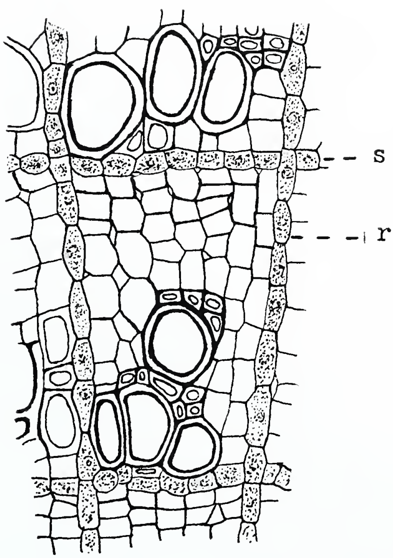


Fig. 7. Transverse section of wood of Dirca, showing storage tissue, *s*, and xylem ray, *r*.

Dirca has characteristically five to nine in a group, forming a sort of network throughout the xylem (Fig. 3.) In Salix the vessels are fairly evenly distributed and are very uniform in size (Fig. 4), while in Carpinus they are erratically grouped and arranged (Fig. 5). Fagus has most vessels per unit area, and all are arranged in definite rows (Fig. 6). Neither grouping of vessels nor nature of the xylem rays seems to have any bearing on the rigidity of the stem; the structure of the fibers as previously described apparently controls this characteristic of the wood.

A unique feature in Dirca is a special storage tissue one cell in width on the inside of every annual ring. The cells resemble those of the xylem rays both in shape and content (Fig. 7).

Summary

1. Some physical characteristics of fibers in the xylem of *Dirca palustris, Salix nigra, Carpinus caroliniana*, and *Fagus grandifolia* are considered as to cause of degrees of pliability in wood.

2. Pliability is apparently associated with striking differences in physical features of the wood-fibers.

3. The walls of the fibers become progressively thicker from the most pliable to the most rigid wood.

4. Width of lumina becomes smaller from the most pliable to the most rigid wood, being four times as wide in Dirca as in Fagus.

5. Length of fiber increases with increasing rigidness of wood, being almost three times as long in Fagus as in Dirca.

6. Xylem rays are characteristically uniseriate or biseriate in Dirca, Salix, and Carpinus, while in Fagus they are of the multiseriate, aggregate or compound type.

Literature Cited

1. Dadswell, H. E. and L. F. Hawley, 1929. Chemical composition of wood in relation to physical characteristics. Ind. and Eng. Chem. 21:973-975.

2. Eames, Arthur J. and Laurence McDaniels, 1925. Introduction to Plant Anatomy. McGraw-Hill, 1931. New York.

3. Garrett, George A., 1931. The mechanical properties of wood. John Wiley and Sons, New York.