FIBER LENGTH VARIATION WITHIN GROWTH RINGS OF CERTAIN ANGIOSPERMS

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ABSTRACT

Fiber length variation across individual growth rings of both juvenile and mature wood of seven southern hardwoods was investigated. In most species, fiber length varied more in mature rings than in juvenile rings.

The measurements show that fiber length variation patterns across rings may differ from ring-to-ring within the same tree as well as among species. Researchers measuring fiber length should be aware of this source of variation.

Additional keywords: *Quercus falcata, Quercus stellata, Quercus nigra, Carya ovata, Carya tomentosa, Liquidambar styraciflua, Nyssa sylvatica,* fiber length, within ring variation, mature wood, juvenile wood.

INTRODUCTION

Large variations are known to exist in fiber length not only between different rings within a tree, but also within individual annual rings. In fact, some researchers have attempted to study fiber length trends by macerating sections of trees or complete rings and have found so much variation within their samples that comparisons among samples were useless. In a study of fiber lengths of whole rings from 63 yellow-poplar trees in East Tennessee, Thorbjornsen (1961) was unable to determine if real differences existed between trees. Fiber length differences within macerated samples of 49 different hardwood species were so great that Bergman (1949) was unable to draw any conclusions about fiber length differences between species.

The general conclusion of researchers working with angiosperms is that latewood fibers are longer than earlywood fibers. The fibers of ash (*Fraxinus excelsior*) and sweetgum (*Liquidambar styraciflua*) increase in length from the first-formed earlywood to a maximum in the latewood (Bosshard 1951; Webb 1964). A consistent difference in length between earlywood and latewood fibers was reported for *Eucalyptus regnans* by Bisset and Dadswell (1949). A general increase in the length of summerwood cells has been reported for *Populus tremula* (Hejnowicz and Hejnowicz 1958), and Liese and Ammer (1958) reported that the length of fibers increases steadily from springwood in annual rings of poplar.

Within-ring variation of the fiber length of 28 angiosperms was investigated by Bisset and Dadswell (1950). They interpreted their measurements to show that in all angiosperms with distinct growth rings (both diffuse-porous and ring-porous), there is a definite increase in fiber length from earlywood to latewood. The most common variation pattern was a curvilinear increase from earlywood to latewood followed by an abrupt decrease in length of last-formed latewood fibers. The decrease in last-formed latewood fibers was attributed, by the authors, to contamination of latewood fibers with earlywood fibers from adjacent growth rings. However, in some species, namely *Carya ovata*, *Ulmus campanestris*, and *Sassafrass albidum*, where the maximum fiber lengths occurred near the center of growth rings, the explanation that the decrease in length of outer latewood fibers resulted from contamination may be challenged. The maximum length of fibers in a storied hardwood (*Petrocarpus angolensis*) reportedly occurs near the middle of the ring (Chalk et al. 1955); and in yellow-poplar, a species with growth rings clearly

Fig. 1

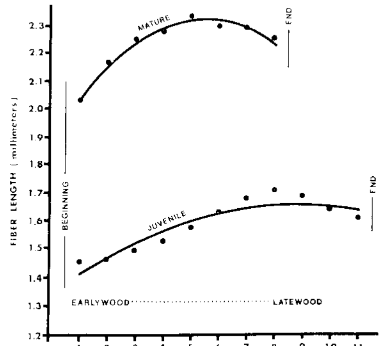


Fig. 2

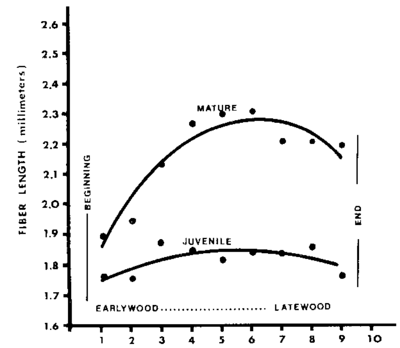


Fig. 3

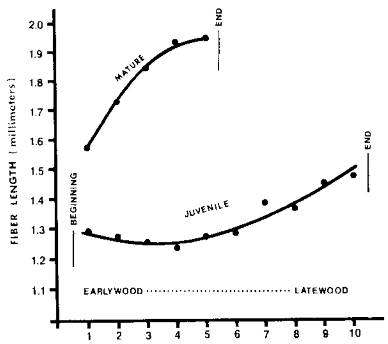


Fig. 4

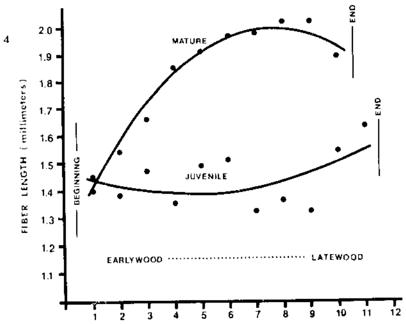


Fig. 5

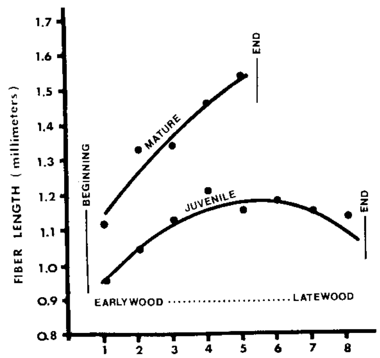


Fig. 6

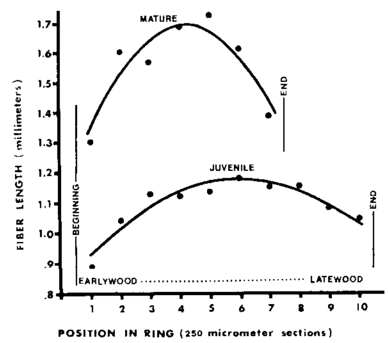
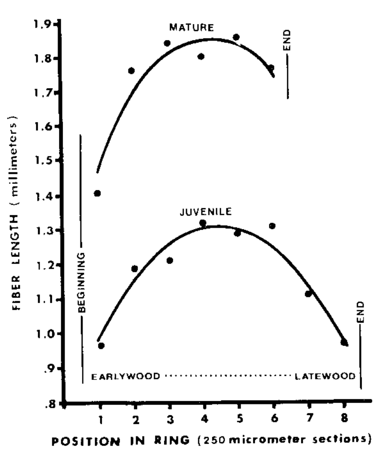


Fig. 7



FIGS. 1–7. Relationship of fiber length to position within rings of juvenile and mature wood.
FIG. 1. Blackgum.
FIG. 2. Sweetgum.
FIG. 3. Red oak.
FIG. 4. Water oak.
FIG. 5. Post oak.
FIG. 6. Mockernut hickory.
FIG. 7. Shagbark hickory.

TABLE 1. *Prediction equations and coefficients of determination based on the observed relationship between fiber length (Y) and position within rings (X)*

Species	Ring Number	Equation	R^2
Blackgum	5	$Y = 1.337 + 0.0719X - 0.0040X^2$	0.85
Blackgum	30	$Y = 1.908 + 0.1499X - 0.0134X^2$	0.97
Sweetgum	5	$Y = 1.703 + 0.0532X - 0.0049X^2$	0.50
Sweetgum	30	$Y = 1.683 + 0.1955X - 0.0160X^2$	0.90
Red Oak	5	$Y = 1.329 + 0.0331X + 0.0052X^2$	0.92
Red Oak	30	$Y = 1.380 + 0.2311X - 0.0229X^2$	0.99
Water Oak	5	$Y = 1.482 - 0.0414X + 0.0043X^2$	0.24
Water Oak	30	$Y = 1.216 + 0.2051X - 0.0134X^2$	0.97
Post Oak	5	$Y = 0.848 + 0.1204X - 0.0110X^2$	0.93
Post Oak	30	$Y = 1.000 + 0.1507X - 0.0093X^2$	0.95
Mockernut Hickory	5	$Y = 0.820 + 0.1141X - 0.0093X^2$	0.92
Mockernut Hickory	30	$Y = 1.041 + 0.3148X - 0.0374X^2$	0.89
Shagbark Hickory	5	$Y = 0.756 + 0.2518X - 0.0282X^2$	0.94
Shagbark Hickory	30	$Y = 1.149 + 0.3487X - 0.0416X^2$	0.89

delineated by a band of terminal parenchyma, Taylor (1965) showed that there was a linear increase in fiber length across growth increments with no decrease in the length of last-formed latewood fibers.

PROCEDURE

Sample blocks containing growth rings 5 and 30 were removed from the southern radius of discs cut at 10 feet above ground from selected species of southern hardwoods. Species investigated were:

- Southern red oak (*Quercus falcata* Michx.)
- Post oak (*Quercus stellata* Wangenh.)
- Water oak (*Quercus nigra* L.)
- Shagbark hickory (*Carya ovata* [Mill.] K. Koch.)
- Mockernut hickory (*Carya tomentosa* Nutt.)
- Sweetgum (*Liquidambar styraciflua* L.)
- Blackgum (*Nyssa sylvatica* Marsh.)

After being boiled in water, the sample blocks containing the rings to be studied were carefully positioned in a sliding microtome, and 250-micrometer-thick tangential sections were removed serially across the entire growth ring, beginning with latewood and progressing toward earlywood.

Maceration was accomplished by treating microtome sections in a mixture of equal volumes of glacial acetic acid and 30% hydrogen peroxide at 60 Celcius for 24 h. The reagent was carefully drawn off with a vacuum hose and the sections were washed with distilled water. Gentle shaking was sufficient to separate the xylem tissue into individual cells.

Macerated fibers were stained with acridine orange dye and their lengths were measured. The length-measurement technique used was a modification of the "graduated bull's eye target method" described by Wilson (1954). Lengths of 50 whole fibers were measured for each microtome section, using the selection technique described by Taylor (1975).

RESULTS AND DISCUSSION

The results obtained for juvenile and mature wood of each species are shown graphically in Figs. 1–7. Data points in the figures are average lengths of the 50 fibers measured from each microtome section. Equations for the curves shown are presented in Table 1.

Average fiber length differences within juvenile growth rings (ring 5) of the oaks, sweetgum and blackgum were not as great as differences within mature growth rings (ring 30) of these species. Fibers of juvenile rings of these species were shortest in earlywood and increased curvilinearly to a maximum in latewood. After the maximum was reached, length decreased in the last-formed latewood of most species. No decrease was evident in latewood fibers of the two oak species in the subgenera *Erythrobalanus* (red oak and water oak).

Mature wood fibers of all species were longer than juvenile wood fibers. In mature wood, fiber length increased quite rapidly as seasonal growth progressed in the earlywood growth zone.

In diffuse-porous species (sweetgum and blackgum) and semi-diffuse-porous species (shagbark and mockernut hickory), fiber length was at a maximum near the middle of growth increments and decreased in the last-formed latewood. The decrease in fiber length of last-formed latewood was not pronounced in water oak and was not observed in red oak or post oak. However, the rate of fiber length increase was greatly reduced in last-formed latewood of red and water oak.

The last-formed fibers in growth rings of the hickories were approximately the same length as the first-formed fibers. However, fibers near the center of growth rings were approximately one-third longer than first-formed earlywood fibers. The explanation given of similar results for shagbark hickory by Bisset and Dadswell (1950) was that latewood fibers contaminated the population of earlywood fibers of adjacent rings. However, the care exercised in the preparation of microtome sections in this study precludes significant contamination.

These results (Figs. 1–7) show conclusively that there are differences in fiber length within seasonal growth increments. They also show that variation patterns are different among species and from ring-to-ring within the same tree. Researchers measuring fiber length should be aware of this source of variation.

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