Clearwood Stiffness Variation In Loblolly Pine And Its Relationship To Specific Gravity And Microfibril Angle

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Extended Abstract

A major limitation to shortening loblolly pine rotation age is the low stiffness (modulus of elasticity) of inner ring wood. Cellulose molecules, themselves, are very high in stiffness. Specific gravity relates to the total number of cellulose chains in a piece of wood, and S2 microfibril angle relates to the orientation of these chains. As such, it is reasonable to expect that both specific gravity and microfibril angle play a significant role in determining the modulus of elasticity of wood.

Specific gravity is well known as a trait with high heritability. S2 microfibril angle was found to be inherited at about the same level as height and diameter (**slide –1**). Both properties are therefore receptive to genetic improvement.

A study was conducted to model how stiffness varies in loblolly pine by ring position and height in tree, and to assess the degree to which stiffness is controlled by microfibril angle and specific gravity. Individual-ring samples from various ring positions (rings 3,5,7,10,15, 20) at each of several heights (1 ft, 4 ft, 7 ft, 10 ft, 13 ft, 16 ft) were tested for modulus of elasticity (MOE) in bending. Specific gravity and microfibril angle were measured on each individual-ring sample. After samples were tested for MOE as whole rings, they were divided into earlywood and latewood components, each component then tested separately.

Specific gravity by ring number from pith, for each respective sampling height, is shown in **slide –2**. Each point represents an average of 24 trees. S2 microfibril angle values are similarly shown in **slide –3**.

Individual-ring samples were tested for modulus of elasticity (MOE) in bending. Samples were 2.1 inches along the grain and 0.115 inches in depth, giving a span to depth ratio of about 18:1. A static load was placed on the radial face, earlywood and latewood being side by side under the load. Radial face loading allowed specimen depth to be kept constant, with sample width fluctuating according to the width of each respective ring or ring component. **Slide –4** shows MOE as a function of ring number from pith, for each respective height. **Slide –5** shows MOE as a function of height, for each respective ring number.

The MOE value associated with a given specific gravity was very dependent on height position in tree. A given specific gravity is associated with a much lower stiffness value if wood is from near the base of the tree, as illustrated in **slide –6**. This is due to microfibril angle values being much higher (less favorable) in the lower portion of the tree. One way to look at three variables in a two-dimensional format is to normalize the dependent variable for one of the independent variables. In **slide –7**, each individual-ring MOE was divided by specific gravity, and this normalized value then plotted over the corresponding microfibril angle value. Data from all rings and all heights, plotted together, showed a very good correlation between microfibril angle and normalized MOE. There was still a fair amount of scatter in the various normalized MOE values associated with a given microfibril angle value, however. This scatter was systematic by within-tree position, as shown in slide –8, where the 24-tree average is plotted for each height/ring position. The increased R^2 value in slide-8 is simply the result of using 24-tree averages instead of individuals. When a correction factor based on percent latewood was applied to each value, as in **slide –9**, the relationship was further improved by a slight amount.

The R^2 values in **slides –7,8,9** are enhanced by the fact that all three variables, MOE, microfibril angle, and specific gravity, are each themselves correlated with ring position and height. Furthermore, the overall range in data has been extended by inclusion of all heights and all ring positions. More relevant from the standpoint of comparing or ranking trees, therefore, is to compare single height/ring positions across trees. **Slide –10** gives the multiple R^2 values found for individual-rings at 4 ft. and 16 ft. in height. While these R^2 values are smaller, they still indicate that the majority of difference in MOE between individual trees, compared at a single height and ring position, is explained by their different microfibril angle and specific gravity values.

After whole-ring samples were tested, rings were then separated into earlywood and latewood components, and the separate components tested for MOE. **Slide –11** shows earlywood and latewood MOE, respectively, plotted by ring number form pith. Latewood stiffness values are 2 to 3 times those of earlywood, depending on height/ring location.

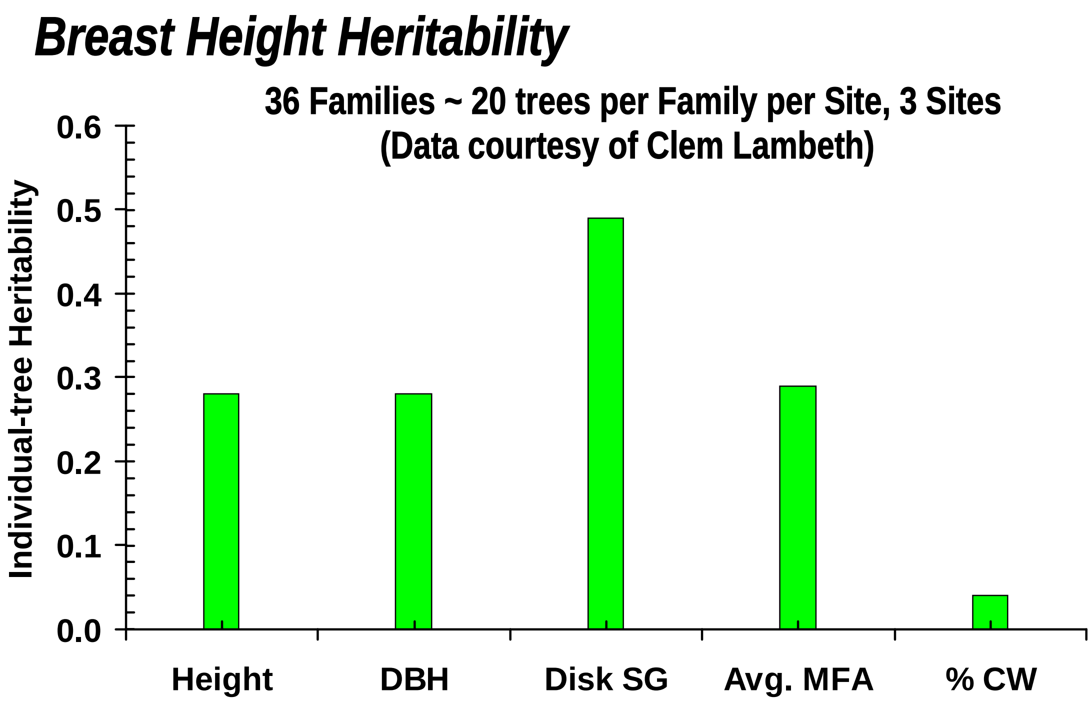
The results of normalizing latewood and earlywood MOE for specific gravity, and then plotting over microfibril angle, is shown in **slide –12**. The regression slopes of the two data sets significantly diverge from each other, indicating that even after both specific gravity and microfibril angle differences were accounted for, latewood still has a slightly higher MOE than earlywood. It suggests that other anatomical factors also influence MOE, in addition to specific gravity and S2 microfibril angle, and in latewood these additional factors are slightly more favorable to stiffness than in earlywood.

Slide –13 provides a look at the ranking consistency among these trees for breast height MOE, tracked over time. The three highest trees for rings 3 and 5 MOE are tracked by increasing ring number from pith. Likewise, the three lowest trees for rings 3 and 5 MOE are tracked by increasing ring number from pith. **In slide –14**, the same three high and three low MOE trees (based on rings 3,5 ranking at breast height) are tracked for their MOE values at 16 feet in height. Results indicate that more thorough sampling than just breast height evaluation at an early age may be required to identify trees that are truly superior in merchantable wood MOE throughout rotation.

Also apparent from **slides –13** and **–14** is the fact that among-tree variability in MOE for inner rings 3,5 was less than half the among-tree variability in MOE for outer rings 10, 15, or 20. Since there is a smaller range in inner ring MOE to select from, it will be harder (take more selection effort) to genetically raise the MOE of inner rings by a given amount.

Slide –15 provides a short summary of highlights from the study.

A more detailed and thorough discussion of the entire study is provided in the following reference: Megraw, Bremer, Leaf, Roers, 1999; Proceedings of the Third Workshop – Connection between Silviculture and Wood Quality through Modeling Approaches; working party S5.01-04; La Londe-Les-Maures, France; Sept. 5-12, 1999; pp 341-349.

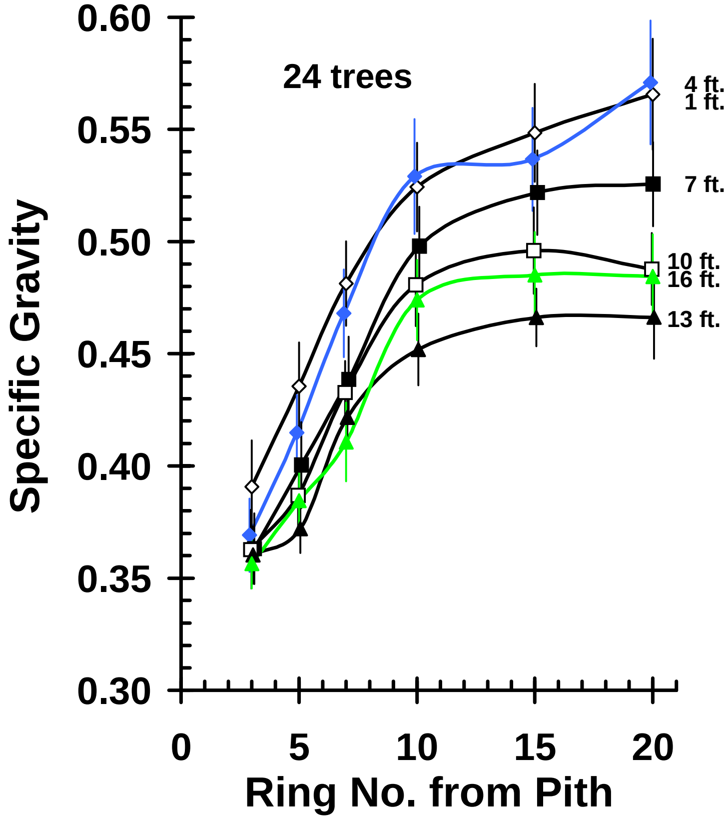

Breast Height Heritability
36 Families ~ 20 trees per Family per Site, 3 Sites
(Data courtesy of Clem Lambeth)
Individual-tree Heritability
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Height
DBH
Disk SG
Avg. MFA
% CW

Slide 1

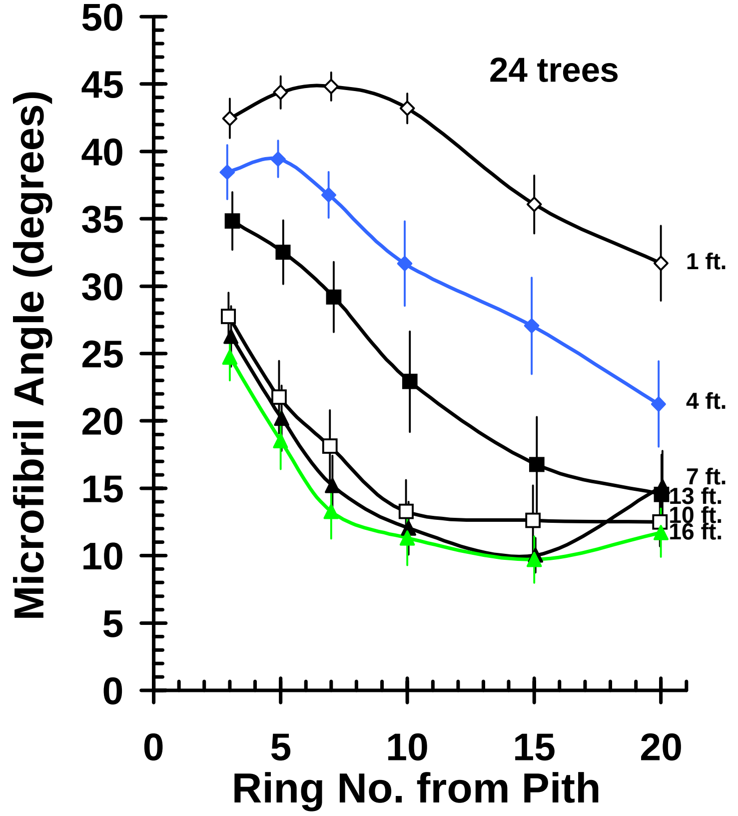
Slide 2

Slide 3

Specific Gravity by Ring No. From Pith



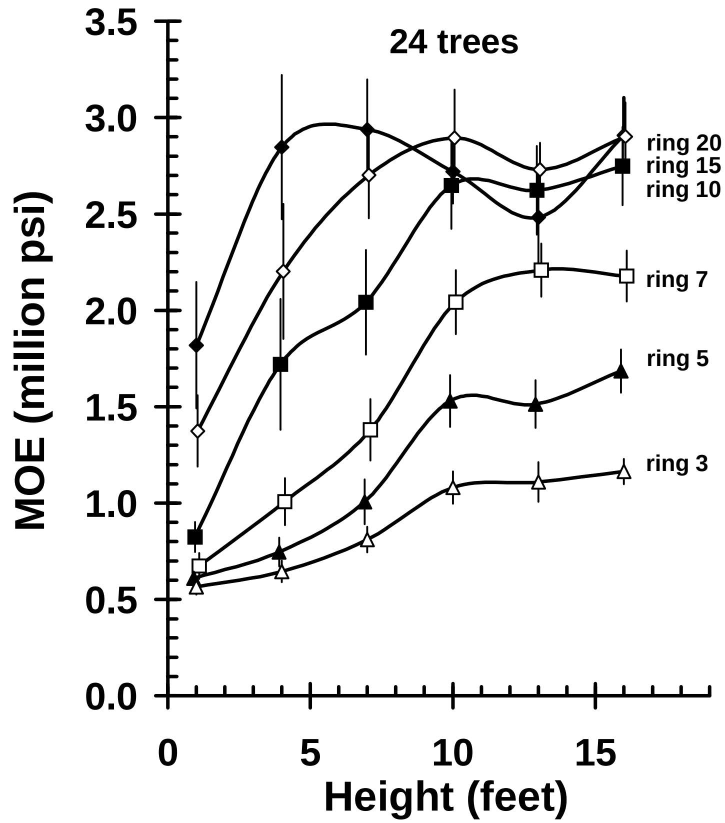
Microfibril Angle by Ring No. from Pith



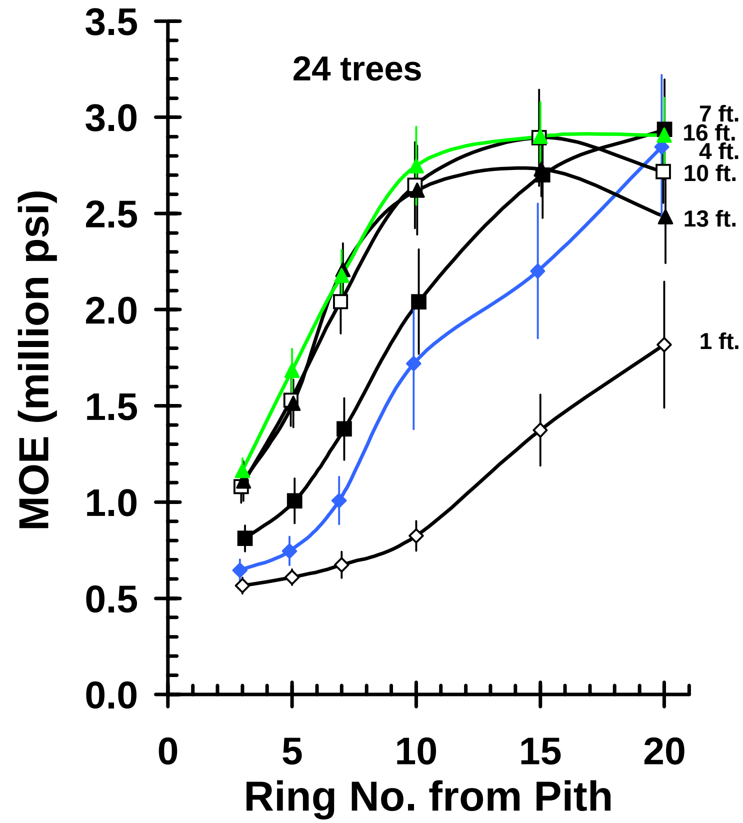
Slide 4

Slide 5

MOE by Height-in-Tree

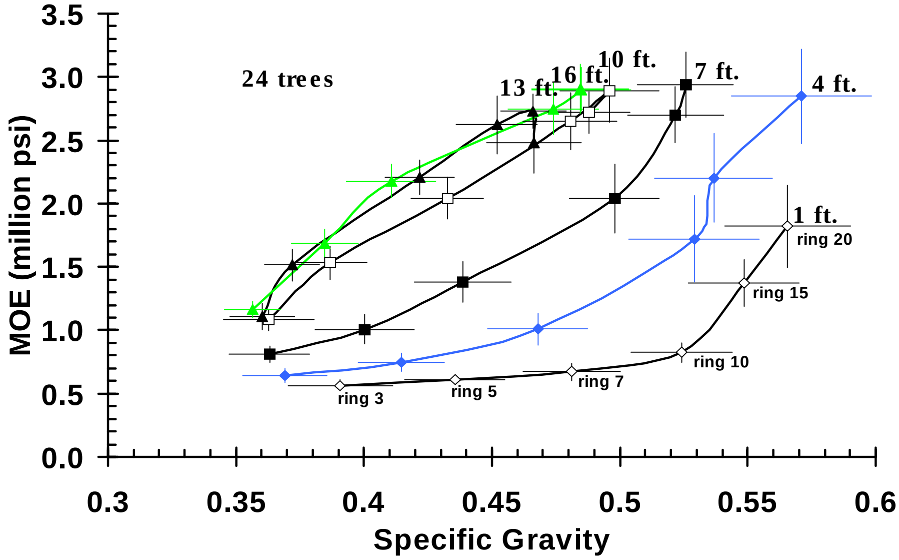


MOE by Ring No. from Pith



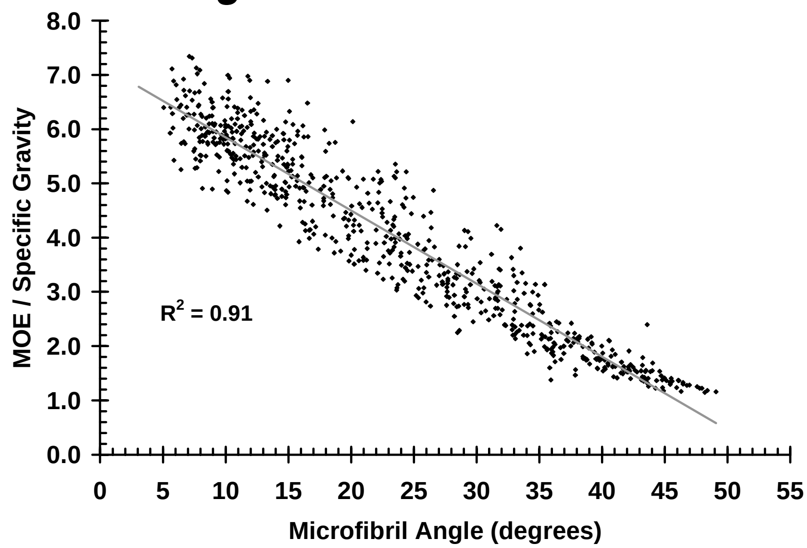
Slide 6

Individual-Ring MOE vs. Specific Gravity



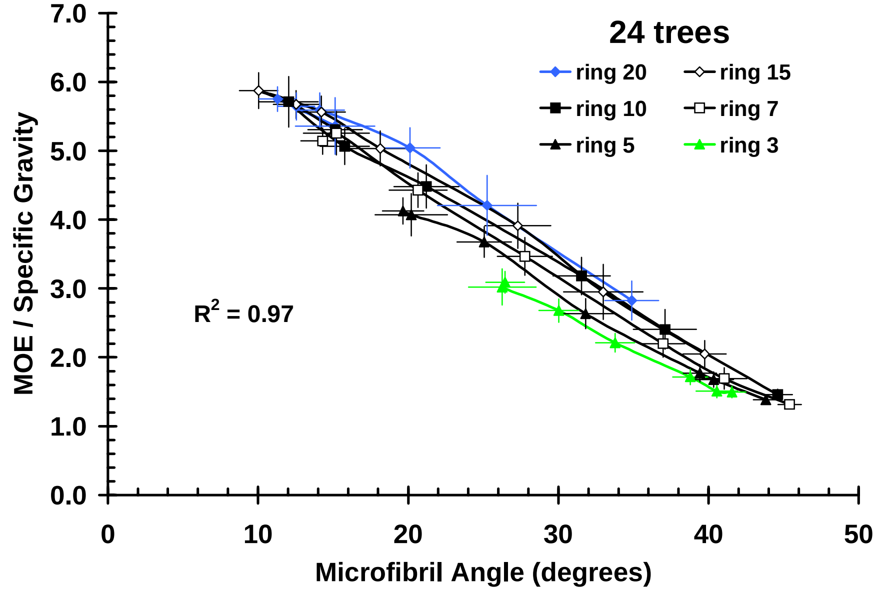
Slide 7

(Individual-Ring MOE) / Specific Gravity vs. Microfibril Angle



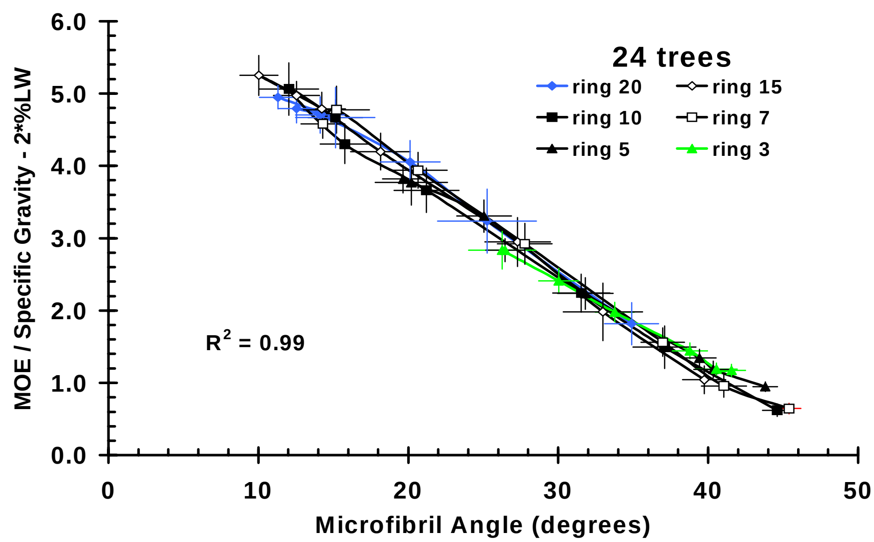
Slide 8

MOE / Specific Gravity vs. Microfibril Angle



Slide 9

Addition of %-Latewood Factor



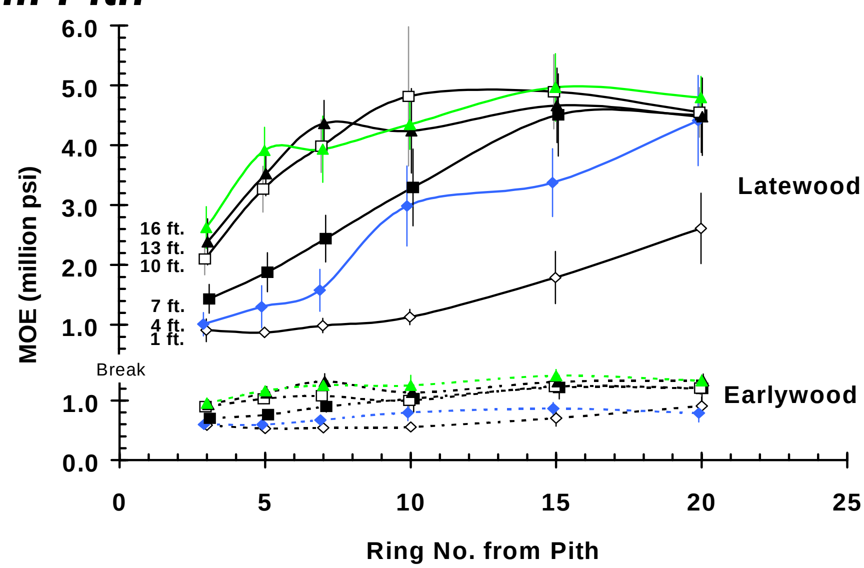
Slide 10

Individual-Ring MOE Regressed Against Microfibril Angle and Specific Gravity

Individual-Ring Location		Multiple R^2
4 ft.	ring 3	0.76
	ring 5	0.80
	ring 7	0.78
	ring 10	0.96
	ring 15	0.89
	ring 20	0.85
16 ft.	ring 3	0.76
	ring 5	0.80
	ring 7	0.78
	ring 10	0.96
	ring 15	0.89
	ring 20	0.85

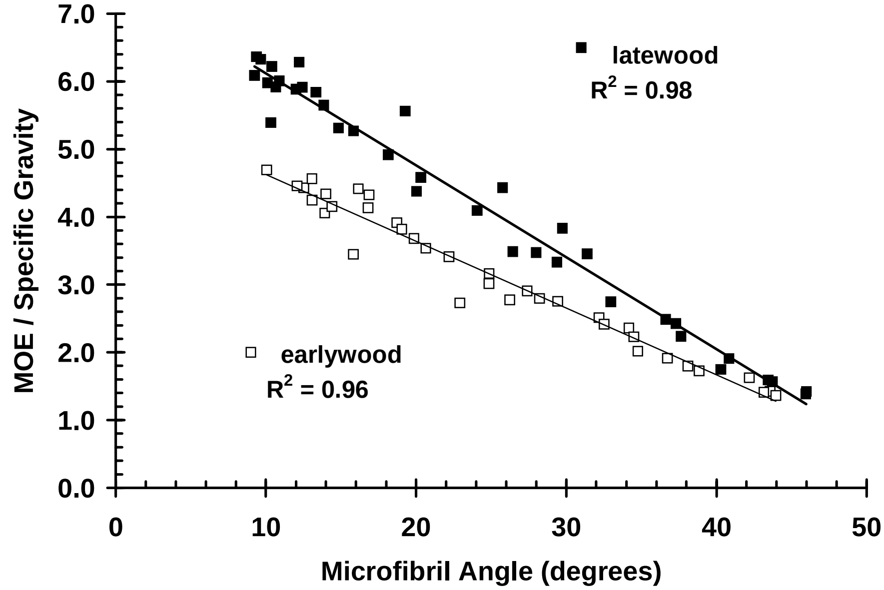
Slide 11

Earlywood and Latewood — MOE by Ring No. from Pith



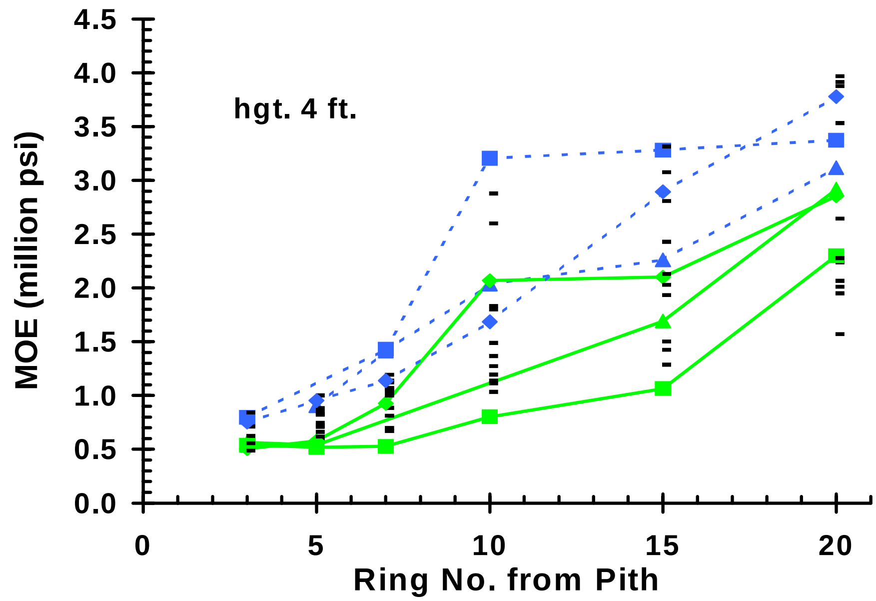
Slide 12

Earlywood vs. Latewood — MOE Normalized for Specific Gravity vs. Microfibril Angle



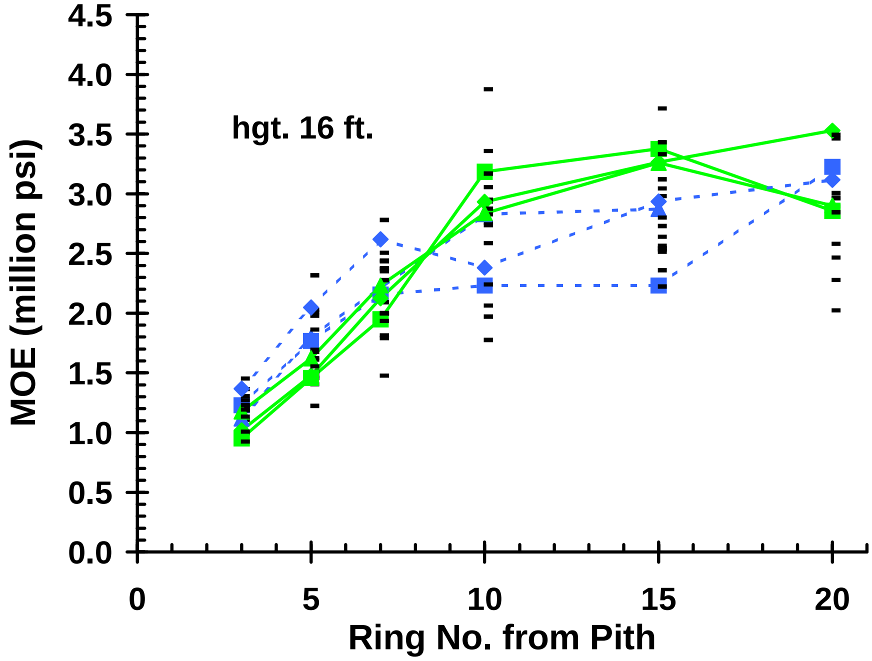
Slide 13

Individual Tree — MOE vs. Ring No. From Pith



Slide 14

Individual Tree — MOE vs. Ring No. From Pith



Slide 15

Summary

- **Modulus of elasticity (MOE) varies greatly and systematically with <u>height</u> in tree and <u>ring from pith</u>**
- **Most variation in MOE (but not all) is due to variation in MFA and Sp. Gr.**
- **Variability in MOE among trees is much less for inner rings than for outer rings**