

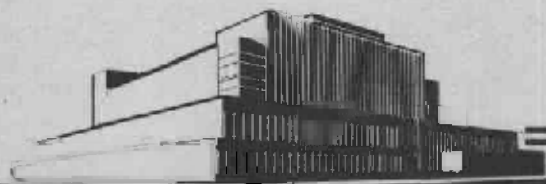
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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE

In Cooperation with the University of Wisconsin

APPLYING FOREST TREE IMPROVEMENT PRACTICES IN THE
LAKE STATES: PRODUCTION OF QUALITY WOOD¹

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The Forest Products Laboratory is particularly interested in seeing that wood quality receives the consideration it deserves in the field of forest genetics. To achieve this objective we work closely with the forest geneticists, try to provide them with an adequate concept of wood quality, and carry on considerable research aimed at the development of more efficient nondestructive techniques and equipment for evaluating the intrinsic quality of wood in living trees. The ultimate goal, of course, is trees that are truly "elite" in all important respects, including the production of wood of greater utility and value in the market place.

In past selection and breeding research, there has been a tendency to overlook or take wood quality for granted, and to place most or all of the emphasis on such desirable silvical characteristics as growth rate, form, branching habit, adaptability to site, and resistance to pests. Some silviculturists, probably a minority of the discipline that spawned most of our present crop of researchers in forest tree improvement, still hold the extreme view that trees which are superior according to their concept of quality will, under proper management, automatically yield the maximum of high-quality products.

Perhaps this should be generally true, as it is in many cases, but there are too many exceptions to justify acceptance of such a philosophy. It is too easy

¹—Based on a paper presented at the Third Lake States Forest Tree Improvement Conference, Grand Rapids, Minn., September 16-18, 1957.

²—Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

to find trees that are superior according to the silviculturists's requirements as to size, form, straightness of bole, and the like, but that contain wood so poor in intrinsic quality that it is unfit for any of the more demanding uses. In such trees, the wood may be poor because of low specific gravity, unevenness of growth, occurrence of compression wood or tension wood, severe cross grain, or any combination of the various physical and structural factors that determine mechanical strength, pulp yields, the tendency to warp, machining characteristics, and other important properties.

This raises the question of what is meant by wood quality. An adequate concept of quality is needed if wood quality is to receive effective consideration in the field of forest tree improvement.

Because of important differences within and between species and the great variety of products made from wood, it is difficult to develop a single, all-inclusive definition of wood quality. From a technological standpoint, wood quality can be defined and given a relative rating according to how well it meets the technical requirements for a particular product or end use. Thus, all high-density wood could be considered as of high quality for charcoal, the low-value product of a woods-scavenging industry that prefers high-density species but can economically process odds and ends of most any sort of wood. One objection to using this basis alone for a wood-quality rating system is that it disregards monetary values and leads to some unrealistic groupings.

A more realistic approach would be a rating system based on how well a bolt, log, or tree meets the technical specifications for the highest value products or uses for which it will qualify. Thus, a high-quality tree could be defined as one with a high proportion of its net volume in wood suitable for conversion into the higher grades of the more valuable end products and in sufficient quantity ordinarily to justify its economical harvest for such products.

Now, what are the characteristics of wood, in addition to size, clearness, and the like, that determine its suitability for various end uses? Wood density, usually expressed as specific gravity, is perhaps the simplest and most useful single index to the suitability of wood for many important uses. Figure 1 shows the relationship between wood density and yields of kraft pulp from southern yellow pines. Note that for every 2-pound increase in wood density, there is produced about 1 pound more of pulp. Stated another way, a cord of high-density southern pine wood will yield about twice as much kraft pulp as a cord of low-density wood of the same species. The same general relationship between wood density and pulp yields holds for all species.

There is also a high degree of correlation between specific gravity and the mechanical strength of all woods. Specific gravity is therefore a primary factor in the segregation of structural-grade timbers that command premium prices in the lumber market, and also in the selection of material for high-grade piling, transmission poles, and other uses where strength is of major importance.

Another key feature is the proportion of summerwood to springwood in the annual growth ring. Springwood is composed of relatively large-diameter, thin-walled cells, and summerwood of smaller, thicker-walled cells. Springwood is lighter in weight, softer, generally weaker, and shrinks more along the grain than summerwood. Thus, the greater the proportion of summerwood to springwood in the annual growth rings, the greater the strength of the wood and the yield of pulp therefrom, and the less the longitudinal shrinkage. On the other hand, it is known that pulp sheets made experimentally of practically pure springwood from southern pines felt better than those made of summerwood;³ also, that the bursting strength and tensile strength of paper tend to increase with increases in the proportion of springwood to summerwood. In contrast, the stiffer summerwood fibers make paper whose resistance to tearing -- a highly essential property for kraft paper -- increases with the proportion of summerwood.

The significance of another feature -- fibril angle -- looms larger as we learn more about it.⁴ Fibrils, which are believed to be composed of strands of cellulose chains, make up the layers of the secondary wall of the wood fibers. Their orientation with respect to the long axis of the fibers is termed the fibril angle. Large fibril angles are the rule in compression wood, an abnormal kind of wood that has extremely poor strength and shrinkage properties, and in normal wood of low density and low mechanical strength. Small fibril angles, in some cases practically parallel to the axis of the fibers, are typical of high-density, strong wood of low shrinkage along the grain.

Figure 2 shows what happens when low-density, high-shrinkage wood is combined in the same board with more stable wood of higher density. In early life -- up to 10 or 12 years of age -- many softwoods tend to make excessive diameter increment when grown on good sites relatively free of competition. During this period, wood density tends to decrease and shrinkage to increase with the rate of diameter growth. The warping that results from combining such wide-ringed juvenile wood with more mature wood formed later in life

³—Chidester, G. H. Maximum Growth of Pulp Fiber per Acre. Am. Pulpwood Assn. Pulpwood Manual, pp. 50-52, 1954.

⁴—Pillow, Maxon Y. Patterns of Variation in Fibril Angles in Loblolly Pine. Forest Products Laboratory Report No. D1935. 11 pp., illus.

is an important cause of degrade in southern pine, and is common in many other second-growth softwoods.

Nonuniform growth is equally undesirable in hardwoods. In hardwoods, however, both wide- and narrow-ringed wood are well suited to important, although quite different, uses. Most hardwoods, unlike the majority of softwoods, tend to increase in density with increases in growth rate. Uniformly dense, wide-ringed, "second-growth" hickory and ash, for example, are preferred for tool handles, athletic equipment, and other products requiring high mechanical strength and shock resistance. On the other hand, the furniture industry prefers soft-textured wood of moderate, uniform growth because of its lower weight, greater stability, and superior machining and finishing properties (fig. 3).

Compression wood, shown in figure 4, is abnormal wood formed largely on the under side of leaning softwoods. Trees that lean 4 degrees or more from the vertical usually contain large amounts of this abnormal structure that is characterized by large fibril angles, excessive shrinkage, and low mechanical strength. In certain combinations with normal wood in the same board, the greater shrinkage of the compression wood causes the piece to twist, crook, or bow on drying.

Tension wood (fig. 5) is an abnormal structure that usually occurs in serious amounts on the upper side of leaning hardwoods. Sweep and crook, common in leaning trees, also favor tension wood formation. Tension wood is made up of a large number of gelatinous fibers that cause serious warping and torn grain in lumber, fuzzy surfaces and buckling of veneer, and make machining and finishing difficult or impossible.

Compression failures (fig. 6), which should not be confused with compression wood, are minute fractures or short, locally deformed areas along the cell walls of fibers, that are caused by excessive endwise forces, as during severe windstorms, careless felling, or rough handling of logs and lumber. These localized areas of damaged fibers, each of which extends across at least several annual rings, constitute an important cause of brashness, which permits wood to break suddenly and completely across the grain with the application of relatively small loads. The wood of certain trees, because of inherent physical or structural weakness, may be more prone to develop compression failures than others. Failure of many of the broken ladder rails and helicopter rotor blades sent to the Forest Products Laboratory for diagnosis can be attributed to compression failures that in most cases should have been detected by inspection of lumber destined for such uses.

Fortunately, the wood-quality factors here discussed are, unlike the weather, something we can do a lot about. They can be modified, controlled, or minimized to a considerable extent through forest management and careful selection and breeding aimed at attainment of specific wood-quality objectives.

Some of the more important quality characteristics, such as specific gravity, are known to be heritable in certain species. Many others, including tension wood and compression wood, can be controlled indirectly by selection and breeding to eliminate certain physical features -- crook, lean, sweep -- that favor the formation of serious reaction wood.

What some workers in forest genetics have overlooked, or failed to take advantage of, is the fact that trees differ as much in wood-quality characteristics as they do in form, growth rate, and other features that have received most of the emphasis to date. Illustrative are some data on the specific gravity of southern pines just obtained in connection with the second resurvey of the State of Mississippi. In this work, the Southern Forest Experiment Station and its cooperators obtained, in addition to the usual measurements, complete increment cores (to pith) from all pines tallied on all of the semipermanent plots established in Mississippi during the second resurvey, the field work for which is about completed. The cores, which will eventually exceed 12,000 in number, were sent to the Forest Products Laboratory for the determination of specific gravity, age, growth rate, percent summerwood, and other quality characteristics.

The objective of this cooperative study was twofold: (1) to identify living trees having exceptionally high or low specific gravity for use as breeding stock or scion material for seed orchards; and (2) to provide more complete data on the quality of the forest resources of Mississippi.

The frequency distribution curves in figure 7 show, for each of the five species, the variation in specific gravity and age of trees 3 inches and larger in diameter at breast height. Especially noteworthy is the magnitude of the differences -- from 0.25 to about 0.8 -- found in this unbiased sample of the pine population of an entire State. Among other important findings, it was learned that specific gravity is strongly correlated with and increases with age; that there are significant differences in specific gravity between species; and that within species specific gravity increases significantly from the northern to the southern part of the State.

What we are seeking, of course, are individual trees that combine exceptionally high specific gravity with superior growth rate, good form, and other desirable characteristics. Such trees will give the greatest yields of kraft pulp -- the chief product of southern pine pulpwood -- and the high-strength structural lumber, timbers, poles, and piling for which dense southern pines are so well suited.

With the white pines, on the other hand, there is less concern regarding high specific gravity than there is about the characteristics -- machining properties and dimensional stability, for example -- that determine the suitability of these species for their more important uses, such as millwork and pattern stock.

In "hard" hardwoods destined for uses requiring high mechanical strength -- tool handles, wood type, athletic equipment -- the objective should be rapid growth and high density. In cabinet hardwoods used chiefly for furniture, paneling, flush doors, and interior trim, the emphasis should be on machining and finishing properties, dimensional stability, and appearance. There is no reason why geneticists should not select and breed for distinctive figure in fine hardwoods, including bird's eye and fiddleback, and possibly even for the deformities -- crotches, burls, and swollen butts -- that produce the most valuable fancy veneers.

The distinctive and highly attractive figure found in the Sherrill hybrid poplar is a fine example of how a normally low-value pulpwood tree can be up-⁵graded from the "beaver-fodder" category into the fancy face-veneer class. —

Now, at the risk of introducing a slightly sour note into this otherwise happy gathering, I would like to make a comment on the emphasis the majority of speakers have placed on the development of better pulpwood trees. One could easily gain the erroneous impression that most of the forest genetics research under way in this country is aimed at supplying more and better raw material for the booming pulp and paper industry.

The pulp and paper people should certainly be commended for their long-range viewpoint, their acknowledged leadership in tree planting, the strides they are making in the management of their rapidly expanding forest properties, and especially on their interest in and support of research, including tree improvement research. They are setting a fine example which, if attendance at this particular meeting is any indication, is not being followed to any great extent by other segments of the wood-using industry.

However this may be, I am strongly of the opinion that, in the interest of improved and more efficient production and utilization of all forest products, our Committee cannot afford to minimize or disregard the present and future requirements of other important wood-using industries. According to the Timber Resource Review, our Nation consumes annually some 12.2 billion cubic feet of wood. Of this total, sawlogs account for 52 percent, pulpwood

⁵—Little, Elbert L., Jr., Brinkman, Kenneth A., and McComb, A. L. Two Natural Iowa Hybrid Poplars. Forest Science, Vol. 3, No. 3, pp. 253-262. 1957.

22 percent, fuel wood 16 percent, veneer logs and bolts 3 percent, and all other products 7 percent. The requirements for both pulpwood and veneer logs and bolts are expected to increase more rapidly than for sawlogs, and demand for fuel wood is on the decline. But for the present, and in the furthest published projections into the future, by far the greatest proportion of the volume of wood required is and will continue to be in the form of lumber and allied products.

These are economic facts that shouldn't be overlooked by genetics researchers not committed to the improvement of any particular forest product. There are in the Lake States, for example, some important industries, including furniture, that are dependent on a continuing supply of high-quality hardwood lumber and veneer. A greater proportion of their raw material needs could and should be supplied from local sources. The area has some of the world's finest cabinet hardwoods -- yellow birch, hard maple, cherry, red and white oaks, ash -- with which to work toward this objective.

Although the Lake States softwood lumber industry is currently at a low ebb, much of the land that once produced some of the Nation's finest softwood sawtimber is still available, although in a rather sorry state from the standpoint of stocking and species composition. But enough progress has been made to demonstrate that, with time and effort, these lands can be rehabilitated. In the planting, including reinforcement planting, that will be an important part of the rehabilitation job, consideration should be given not only to the quality of the pulpwood that will be removed in thinnings, or in such premature clear cutting as may be done, but also to the quality and value of the final crop when harvested at maturity.

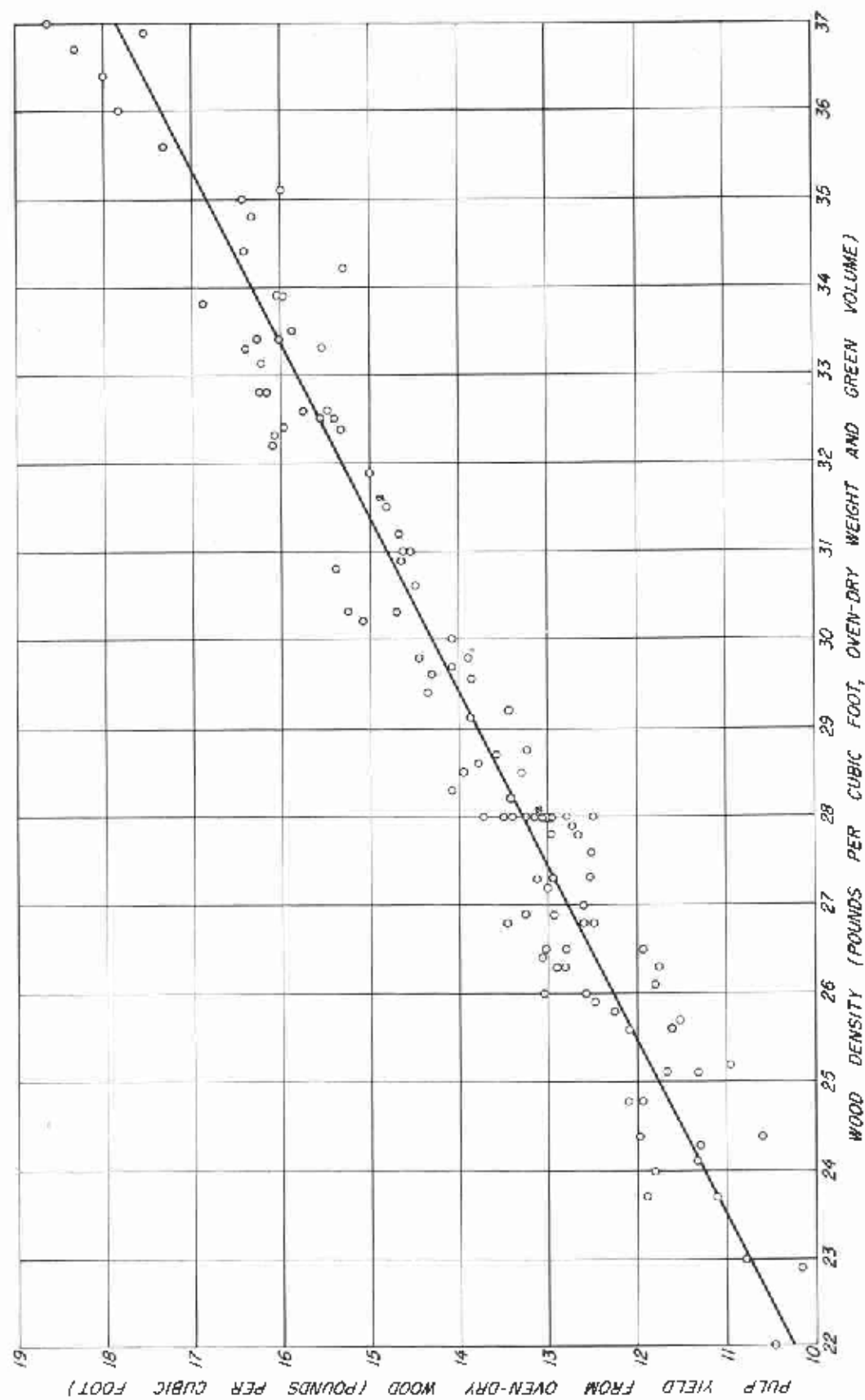


Figure 1. -- Relationship between wood density and kraft pulp yields of southern yellow pine pulpwood.

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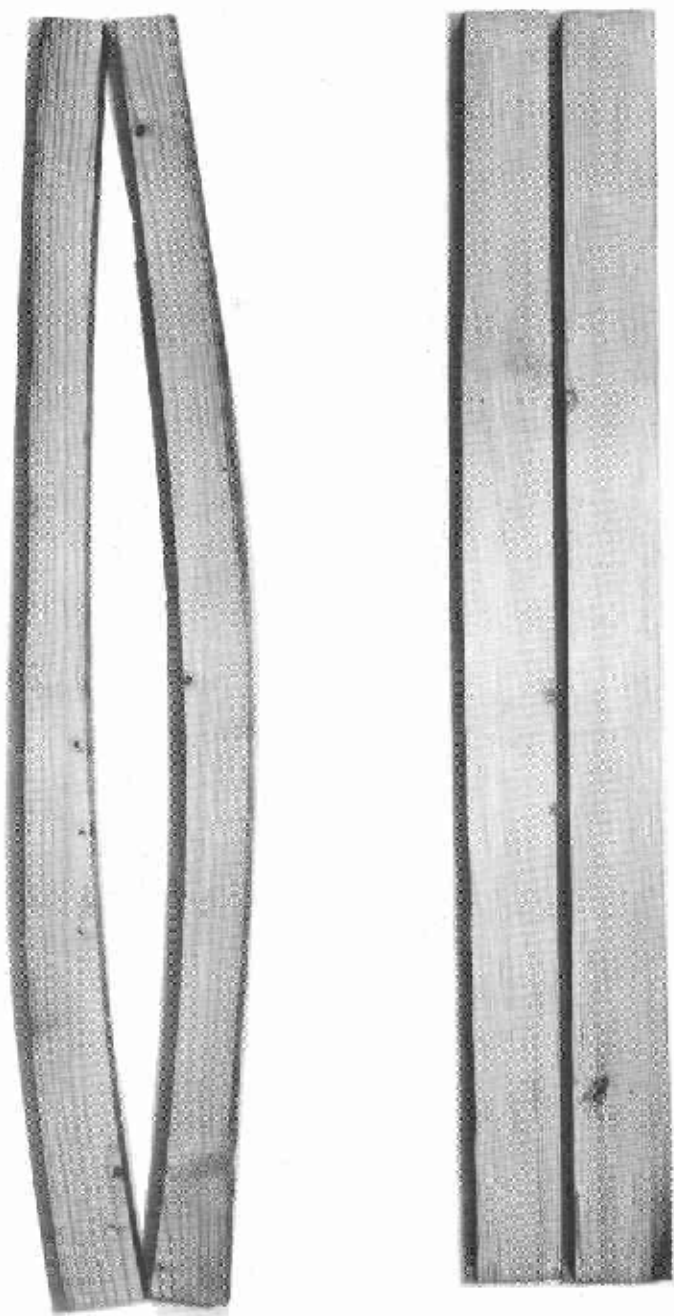


Figure 2. --(Left) Two 2 by 4's ripped from a 2 by 8 sawed approximately through the pith of slash pine which grew very rapidly in the juvenile stage and then at a more moderate rate. Warp is due to greater longitudinal shrinkage of the wide-ringed, low density, juvenile wood, as compared to the older, more stable wood grown at more moderate rate. (Right) Two 2 by 4's from a 2 by 8 sawed approximately through pith of slash pine grown at an even, moderate rate. Here there is little or no stress due to differential shrinkage, hence no warp.

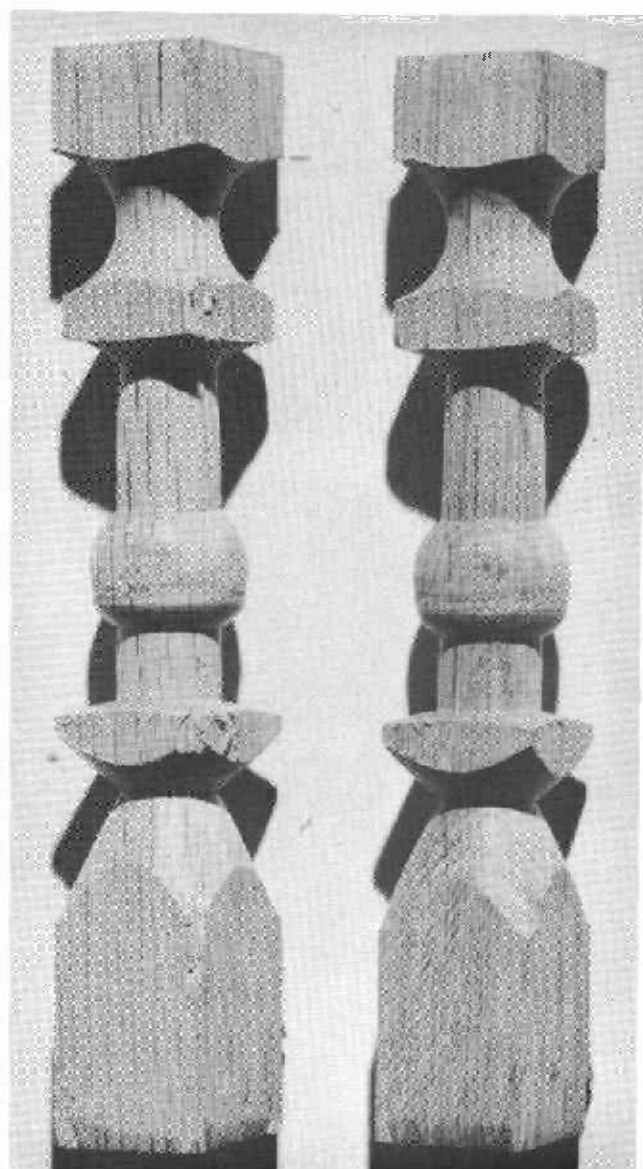


Figure 3. --Standard machining-test turnings of samples of red oak from two different trees. Left, wide-ringed, high-density wood; note numerous machining imperfections. Right, wood of more moderate, even growth and lower density has almost perfect machining properties.

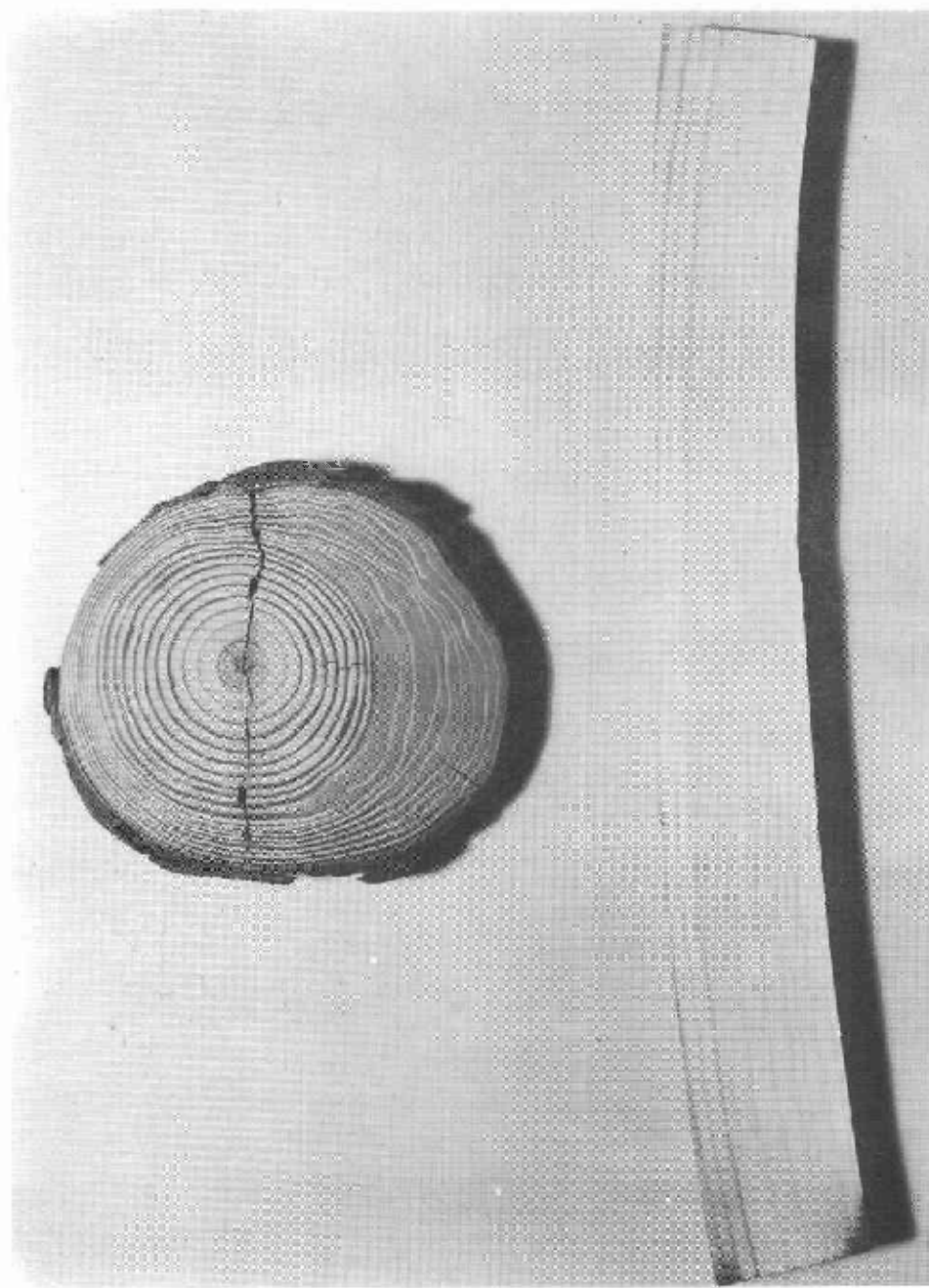


Figure 4. --Cross section of young slash pine showing eccentricity typical of compression wood formed on under side of leaning tree. Below, a 1-inch board that has warped because of greater longitudinal shrinkage of compression wood as compared to normal wood.

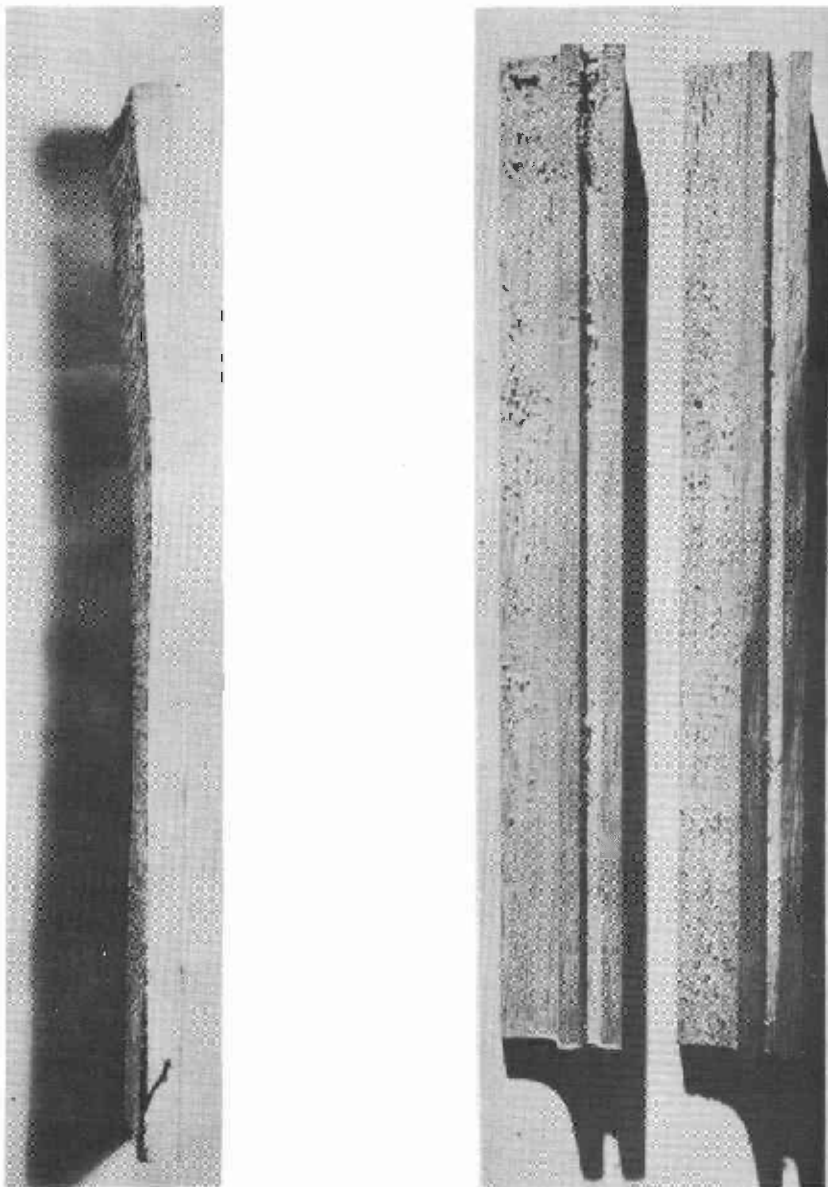


Figure 5. --Elm board (left) that has warped due to serious tension wood.
Moldings (right) made from catio, showing torn grain and fuzziness
in spots containing large number of gelationous fibers.

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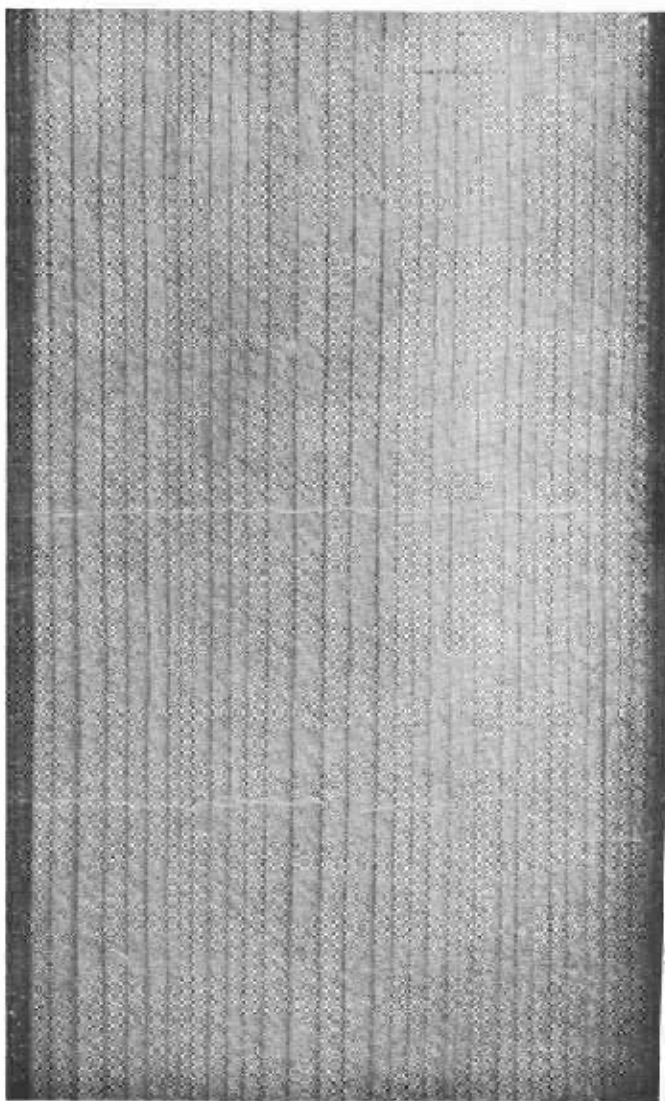


Figure 6. --Clearly visible compression failures found in Sitka spruce ladder rail. If used, this ladder would have broken abruptly, along lines of compression failures, with the application of even relatively light load.

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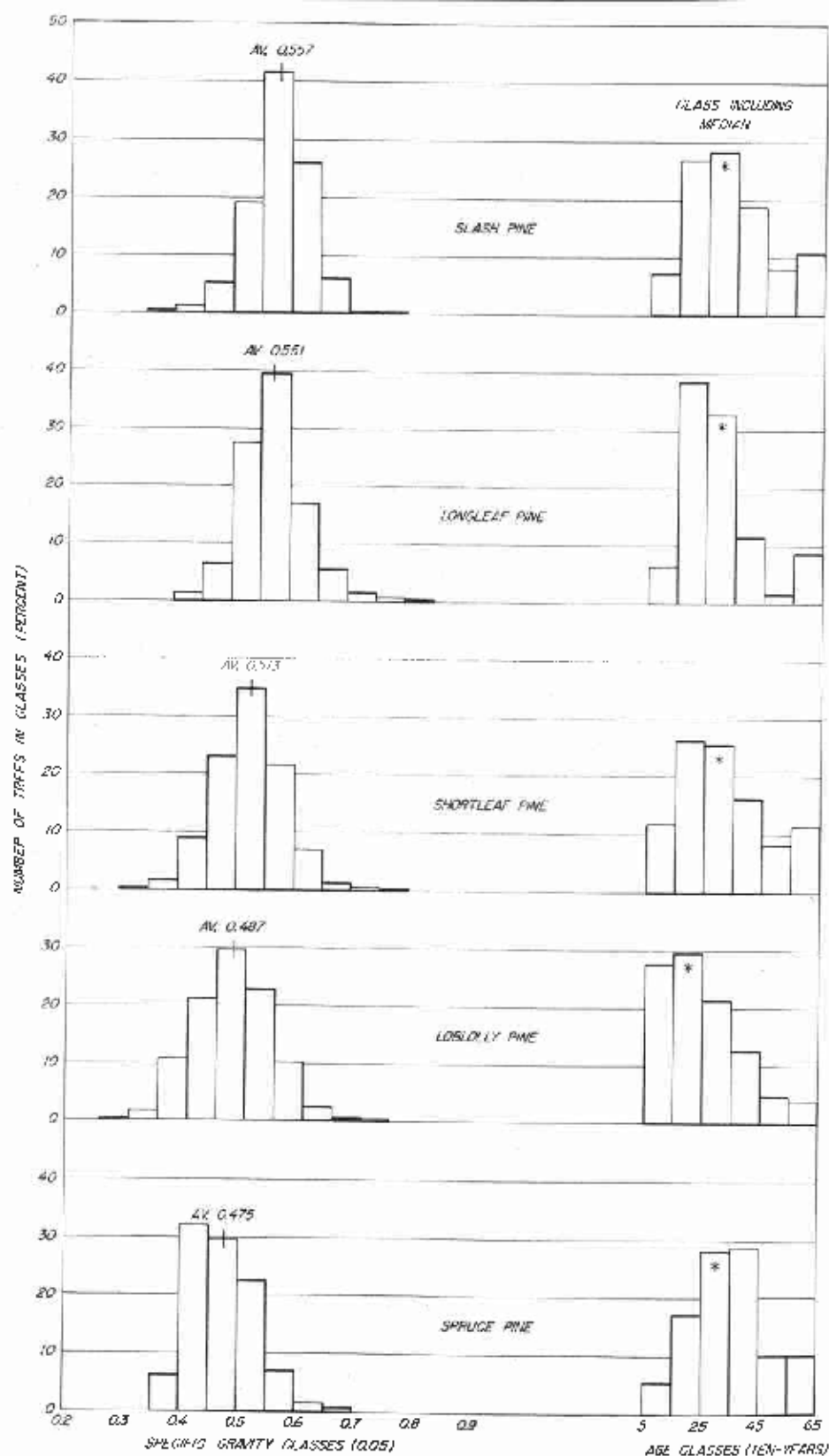


Figure 7. -- Frequency distribution of specific gravity values (at diameter at breast height) and age for five species of southern pine in Mississippi. Based on data from trees on all permanent plots sampled in the third Forest Survey of Mississippi. Field sampling by Southern Forest Experiment Station and cooperators; laboratory determinations by Forest Products Laboratory.