GROWTH RATE AND BENDING PROPERTIES OF SELECTED LOBLOLLY PINES[1]

R. G. Pearson

Professor

Department of Wood and Paper Science, North Carolina State University

Raleigh, NC 27650

and

B. E. Ross

Former Graduate Student

Duke University, Durham, NC 27706

(Received September 1982)

ABSTRACT

The modulus of rupture and modulus of elasticity in center-point bending were determined for ½- × ½- × 10-in. specimens cut between pith and bark from twelve trees of loblolly pine of different growth rates. Six of these trees were fast-grown, 15-year-old, genetically selected stock; 3 trees each came from a 25-year-plantation and a 41-year-old forest. The original location of the specimens in the trees was between 11 and 14 ft above the ground. The average diameter of the trees at breast height was approximately 8¼ in. for each population.

The specific gravity, modulus of rupture, and modulus of elasticity of the wood from the three populations showed a marked initial trend of increasing magnitude with distance from the pith. At distances from the pith greater than about 2½ in., there was little or no change in the properties of wood from the 25- and 41-year-old trees. The properties of the wood from the 15-year-old trees continued to show an increase for at least about 4 in. from the pith. For a given distance from the pith, the properties were, on average, higher in the older trees than in the younger trees. When the properties were related to the number of growth rings from the pith, however, there were no significant differences between the properties of wood from trees of different growth rates. Similarly, rate of growth did not appear to affect the relationships between specific gravity, modulus of rupture, and modulus of elasticity. Consequently, although fast-grown trees contain a larger volume of juvenile wood than more slowly grown trees, the properties of their mature wood should not be significantly reduced by the fast growth rate.

Key words: Growth rate, static bending properties, loblolly pine, modulus of rupture, modulus of elasticity, specific gravity, juvenile wood.

INTRODUCTION

Commercial plantings of southern pine are now mainly from stock genetically selected for desired characteristics, especially fast rate of growth, a feature that is enhanced by modern silvicultural practices.

A major effect of this fast growth rate is that the trees will have a larger volume of juvenile wood, i.e. the relatively low density wood within about the first 10 growth rings from the pith (Zobel et al. 1972), than present commercial trees. There is also some concern that fast growth rate may lead to the production of wood of lower mechanical properties overall. The objective of the study described

[1] This paper is submitted for publication as Paper No. 6565 of the Journal Series of the Agricultural Research Service, North Carolina State University.

Wood and Fiber Science, 16(1), 1984, pp. 37–47

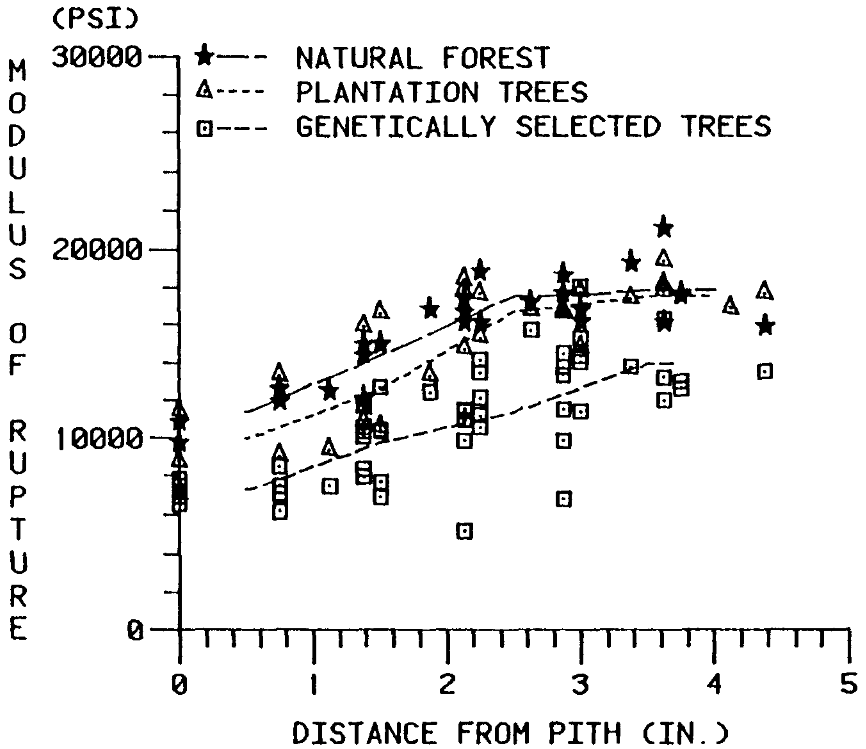

FIG. 1. Variation of modulus of rupture with distance from pith. Lines connect average values at 1-in. intervals for each population.

in this paper was to determine if loblolly pine genetically selected for fast growth rate showed signs of a general reduction in its mechanical properties.

TEST MATERIAL

Grateful acknowledgement is made to Westvaco Company for supplying logs from three populations of loblolly pine of different ages and rates of growth: a naturally regenerated stand 41 years old, a plantation of 25-year-old trees from ordinary commercial stock, and 15-year-old trees from parents genetically selected for their fast rate of growth.

All trees from the three populations grew in the same general area near Pitch Landing, South Carolina, and none of those selected had received any artificial fertilization. Additional information, including the results of other tests on the material, is given in a previous paper (Pearson and Gilmore 1980).

Twelve logs 4 ft long were selected, their lower ends being originally located about 11 ft above ground level in the growing trees. Six logs came from the 15-year-old population and three from each of the other two populations. The average diameter at breast height of the trees supplying these logs was 8.3 in. for the 15-year-old population and 8.2 in. for the other populations.

From each log were sawn three quarter-sawn planks 1½ in. thick. One was a diametral plank and the other two planks were cut at right angles to it. This thickness enabled the planks to be machined to a thickness of ⅝ in. centered on

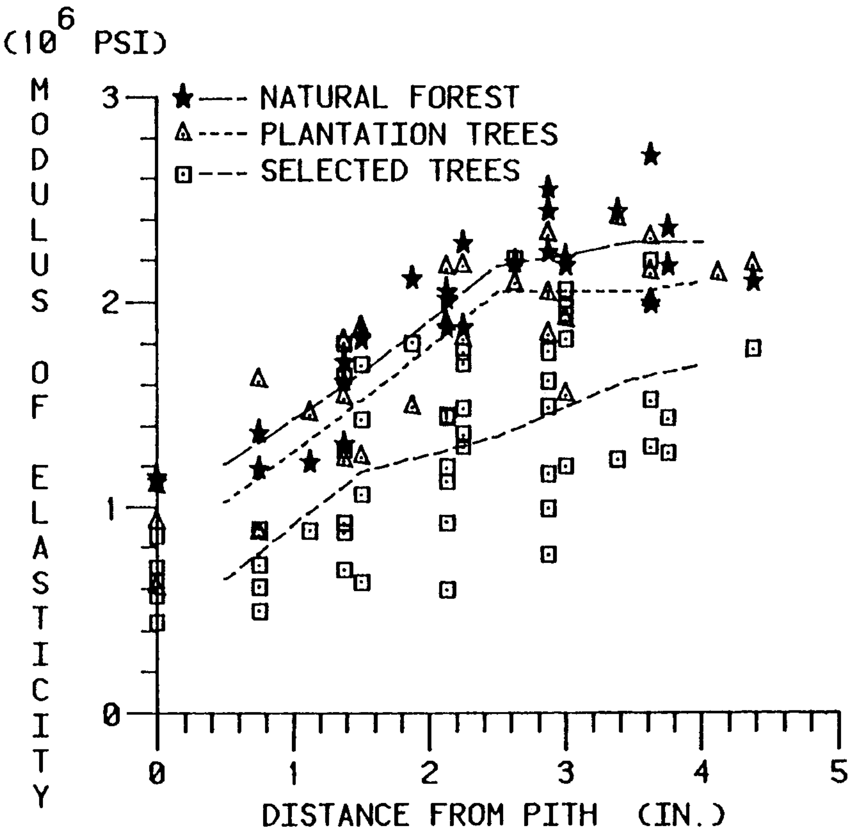

FIG. 2. Variation of modulus of elasticity with distance from pith. Lines connect average values at 1-in. intervals for each population.

TABLE 1. *Three populations of different ages and growth rates: effect of distance from the pith.*

Property	Population age (yr)	Average value of property at average distance from pith (in.)				
		0+	1+	2+	3+	4+
Age (yr)	41	3.0	10.6	18.7	27.1	34.0
	25	1.9	7.8	13.9	19.7	22.1
	15	1.0	4.0	7.7	10.6	13.5
No. of specimens	41	4	7	9	7	1
	25	5	7	9	6	2
	15	11	13	18	11	1
Specific gravity	41	0.48	0.52	0.61	0.63	0.63
	25	0.41	0.47	0.58	0.60	0.57
	15	0.37	0.40	0.45	0.51	0.52
Modulus of elasticity (10^6)	41	1.21	1.66	2.17	2.29	2.09
	25	1.02	1.52	2.05	2.05	2.15
	15	0.65	1.18	1.35	1.63	1.78
Modulus of rupture (psi)	41	11,300	14,400	17,500	17,800	15,800
	25	9,910	12,600	16,700	17,500	17,200
	15	7,230	9,760	11,400	14,000	13,500

TABLE 2. *Three populations of different ages and growth rates: effect of age on properties.*

Property	Pop. age (yr)	Average value of property at average number of rings from pith 0+	2+	5+	10+	15+	20+	25+	30+
No. of specimens	41	2	—	4	6	5	6	2	3
	25	3	3	5	7	5	4	1	—
	15	9	12	21	12	—	—	—	—
Specific gravity	41	0.48	—	0.46	0.56	0.59	0.62	0.62	0.64
	25	0.40	0.43	0.47	0.57	0.59	0.59	0.63	—
	15	0.38	0.39	0.44	0.51	—	—	—	—
Modulus of elasticity (10^6 psi)	41	1.14	—	1.27	1.85	2.05	2.34	2.35	2.21
	25	0.88	1.31	1.53	2.08	1.96	2.08	2.30	—
	15	0.64	1.04	1.36	1.64	—	—	—	—
Modulus of rupture (psi)	41	10,300	—	12,300	15,500	17,000	17,900	18,600	17,000
	25	9,080	10,600	13,100	16,700	16,800	17,500	19,400	—
	15	7,260	8,980	11,400	13,900	—	—	—	—

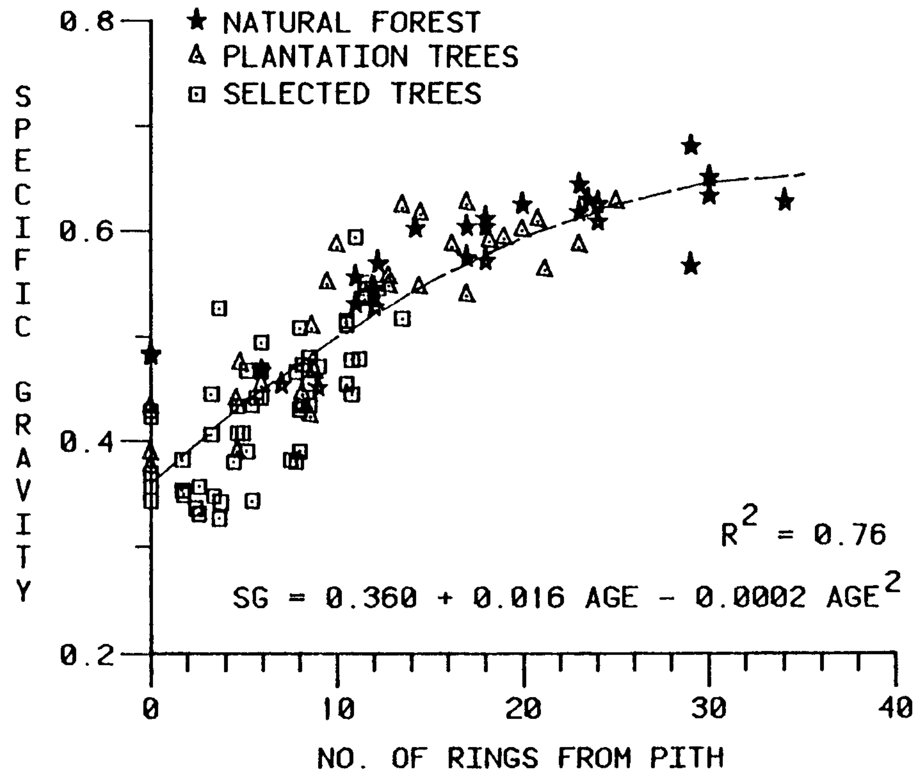

FIG. 3. Variation of specific gravity with age of wood.

the true radius of the cross section and then ripsawn into ⅝-in.-wide strips. The strips were dressed to ½ in. square and cross-sawn into 10-in. lengths as free from sloping grain, knots, compression wood, and other defects as possible. A record was kept of the original position of the center of each selected specimen relative to the pith, due allowance being made for saw kerf and planer shaving dimensions. For some logs, there was more than one specimen available at the same distance from the pith. The clearest of these was used for the tests, the others being discarded. Between eight and eleven specimens, depending mainly on log diameter, were selected from each log such that virtually each growth ring was included. Because of the thickness of the original planks, no specimens contained wood from between about ¼ in. and ⅓ in. from the pith. Estimates were made of the number of growth rings from the pith to the center of the specimen. Advantage was taken of the diameter and age of the trees being known to reduce the confusion in counting rings caused by the prevalence of false rings in loblolly pine.

TEST PROCEDURE

The specimens were brought to equilibrium moisture content in a room maintained at 70 F and 65% relative humidity. They were then tested in a 500-lb capacity Instron testing machine in center-point bending over a span of 7 in., the loading being applied to the tangential face nearer the pith at a rate of movement of the loading head of 0.1 in./min. An autographic record was made for each

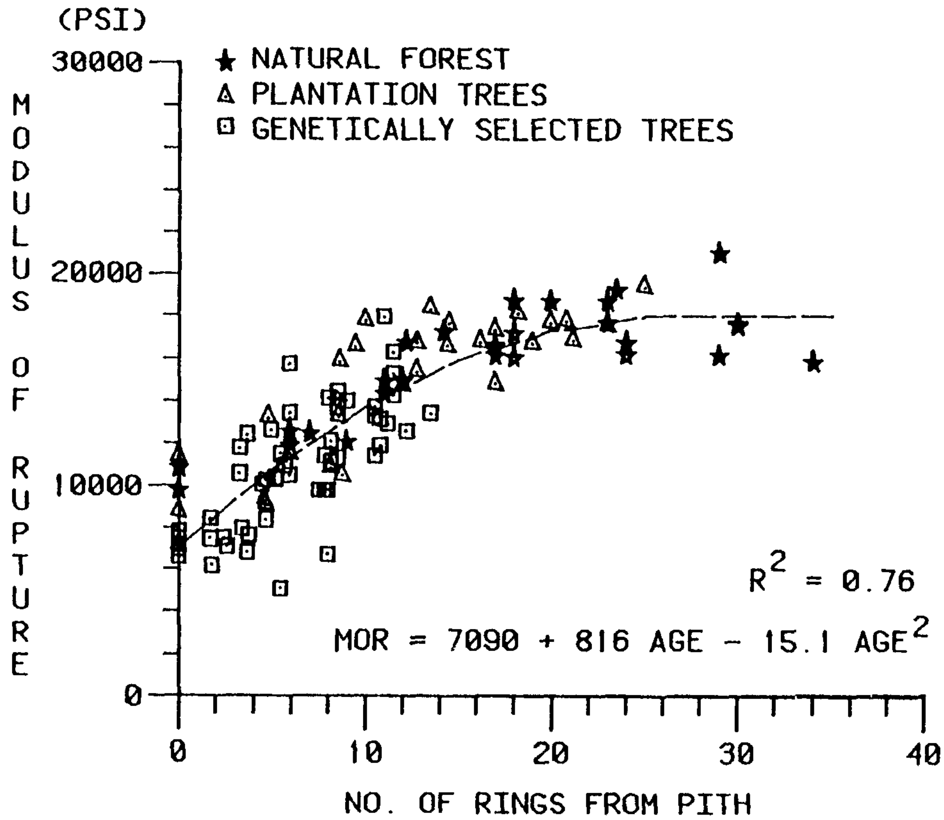

FIG. 4. Variation of modulus of rupture with age of wood.

specimen of the load versus head displacement, the latter being taken as a satisfactory estimate of the midspan deflection for these comparative tests.

TEST RESULTS

The specific gravity (SG) (based on oven-dry weight and volume at test), modulus of elasticity (MOE), modulus of rupture (MOR), and moisture content (MC) were determined for each specimen. The average moisture contents of the specimens from the 41-, 25- and 15-year-old forests were 9.4%, 9.5% and 9.2%, respectively. To minimize the effect of the small differences in MC between the specimens, the values of MOR and MOE were corrected to 12% moisture content by the procedure given on page 4.32 of the Wood Handbook (USDA 1974).

The average values of the properties within 1-in. intervals from the pith are summarized in Table 1. Note that values in the last column are based on only 1 or 2 test results.

Table 2 is similar to Table 1, but gives the average values for various intervals of number of growth rings from the pith, i.e. increments of age, instead of distance from pith.

The manner in which MOR and MOE varied with distance from pith is illustrated in Figs. 1 and 2, respectively. Lines based on the mean values in Table 1

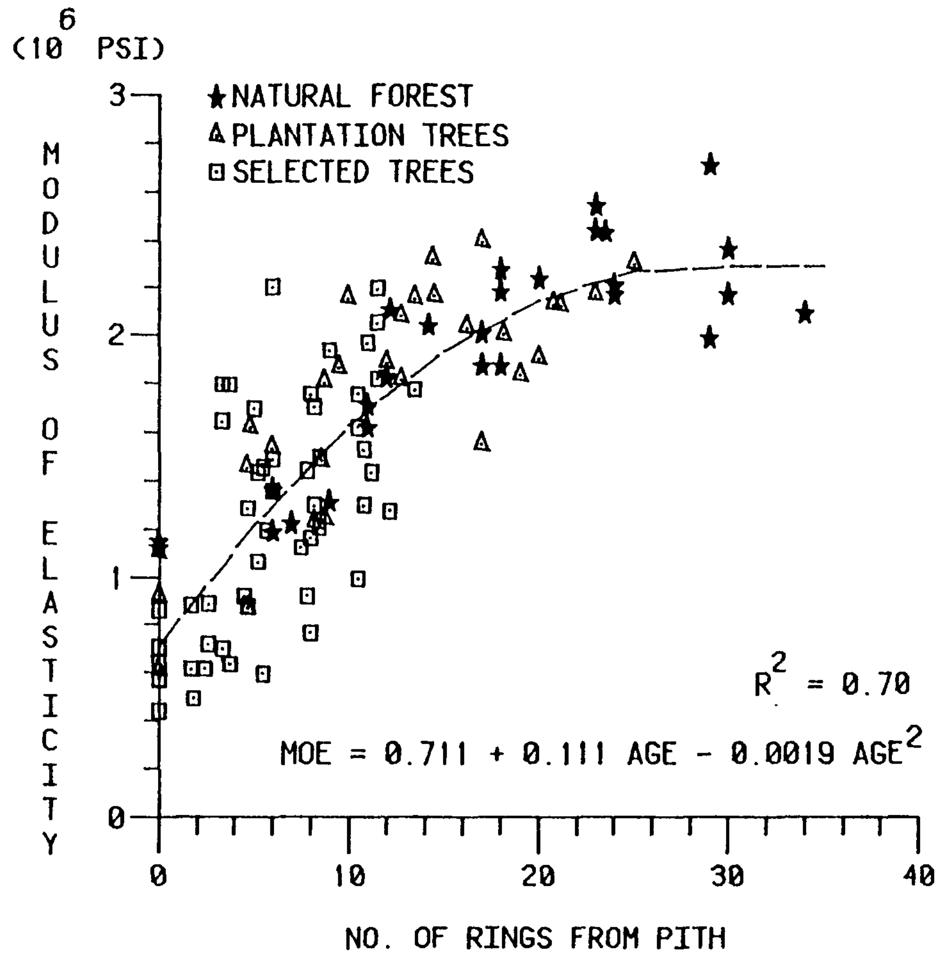

FIG. 5. Variation of modulus of elasticity with age of wood.

have been drawn in Figs. 1 and 2 to emphasize the marked difference between the properties of the wood from the three populations at various distances from the pith. As may be seen from Table 1, a similar pattern of variation with distance from pith applied for SG. The SG, MOR, and MOE are plotted against number of growth rings from the pith in Figs. 3, 4 and 5, respectively. The MOR and MOE are plotted against SG in Figs. 6 and 7, respectively, while MOR is plotted against MOE in Fig. 8.

The intermingling of the values for the three populations evident in Figs. 3 through 8 indicates visually that population differences did not affect significantly the relationships between the respective properties in those figures. Regression equations were calculated for the separate populations but, as expected, they did not differ significantly from each other. Consequently, regression equations were calculated for the combined populations and are given in the figures, together with the coefficient of determination. Root mean square values of the deviations of the test results for each population from the appropriate combined regression

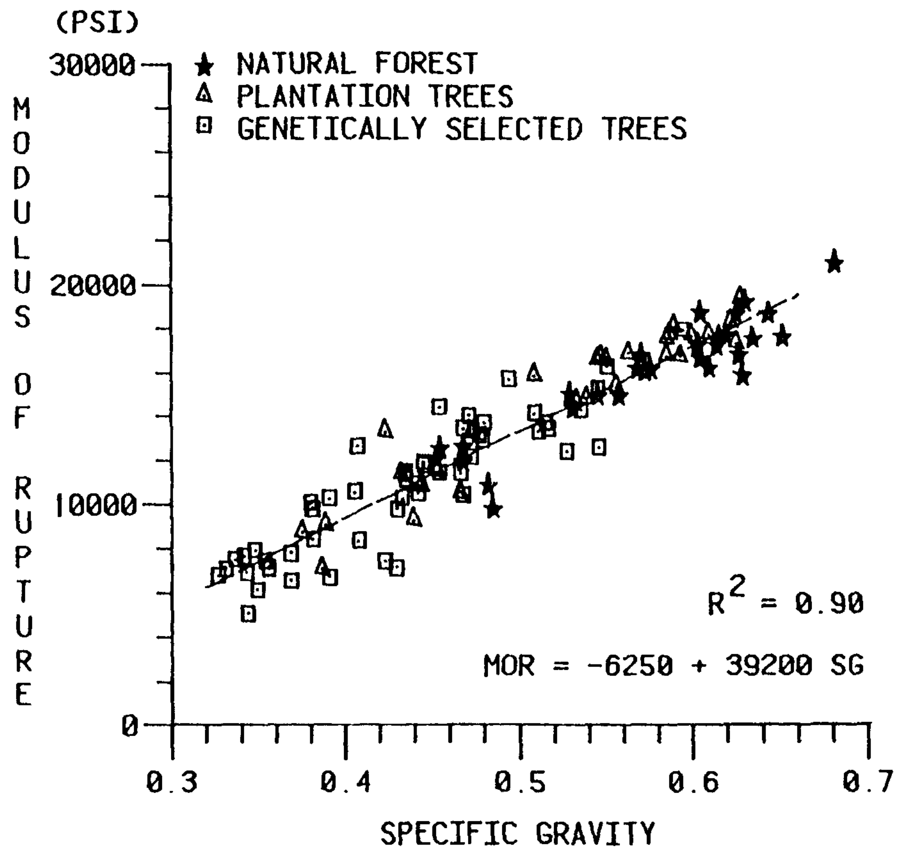

FIG. 6. Variation of modulus of rupture with specific gravity.

equation were computed and were also not significantly different from each other, confirming that the population differences were not significant.

DISCUSSION

Table 1 and Figs. 1 and 2 show that the properties at first increased markedly with distance from the pith for all populations but then tended to level off at about 2½ in. from the pith for the 25- and 41-year-old trees. The properties of the wood from the 15-year-old trees continued to increase for about 4 in. from the pith. Since only one specimen was more than 4 in. from the pith, the trend at larger distances from the pith was not established for the fast-grown wood. The tests thus provide further illustration of the larger volume of lower strength wood produced by fast-grown trees.

The average values of the properties of the wood at a given distance from the pith differed markedly for the three populations, at least up to the levelling-off point for the older populations. The older the population, the higher was the average value of the property at a given distance from the pith. These differences, however, were associated with the differences in the age of the wood at those distances, the older populations having more rings per inch. Figures 3, 4, and 5 show that the trend of the properties with age was similar for the three populations.

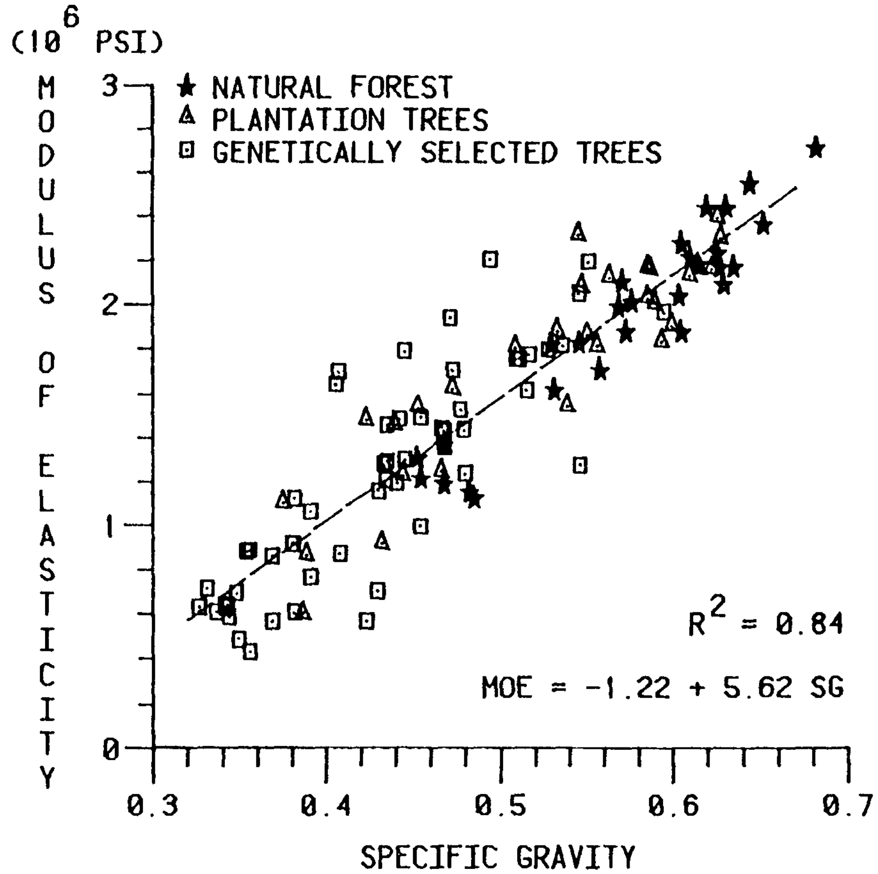

FIG. 7. Variation of modulus of elasticity with specific gravity.

The properties of the wood from the 15-year-old trees were more variable than those from the older trees. The specimens from these trees contained relatively few growth rings, so their properties depended very much on whether the extreme fibers were earlywood or latewood. Price (1928), however, has shown that such specimens still correctly estimate the mean.

Extremely high correlations were obtained for MOR and MOE with SG and with each other, R^2 being 0.84, 0.90 and 0.90, respectively, as illustrated in Figs. 6 through 8. These figures also show clearly that differences in population age and rate of growth did not significantly affect the relationship between the respective properties. This was confirmed by the nonsignificance of differences between the regression equations for the three populations. This result is in line with the findings by Zobel (1971) that SG and rate of growth are not significantly correlated genetically, and by Talbert et al. (1983) that the SG of juvenile and mature wood are significantly correlated genetically. Consequently, the wood from the young trees would be expected to have continued to increase in density and mechanical properties with distance from the pith for some time had the trees been allowed to live longer.

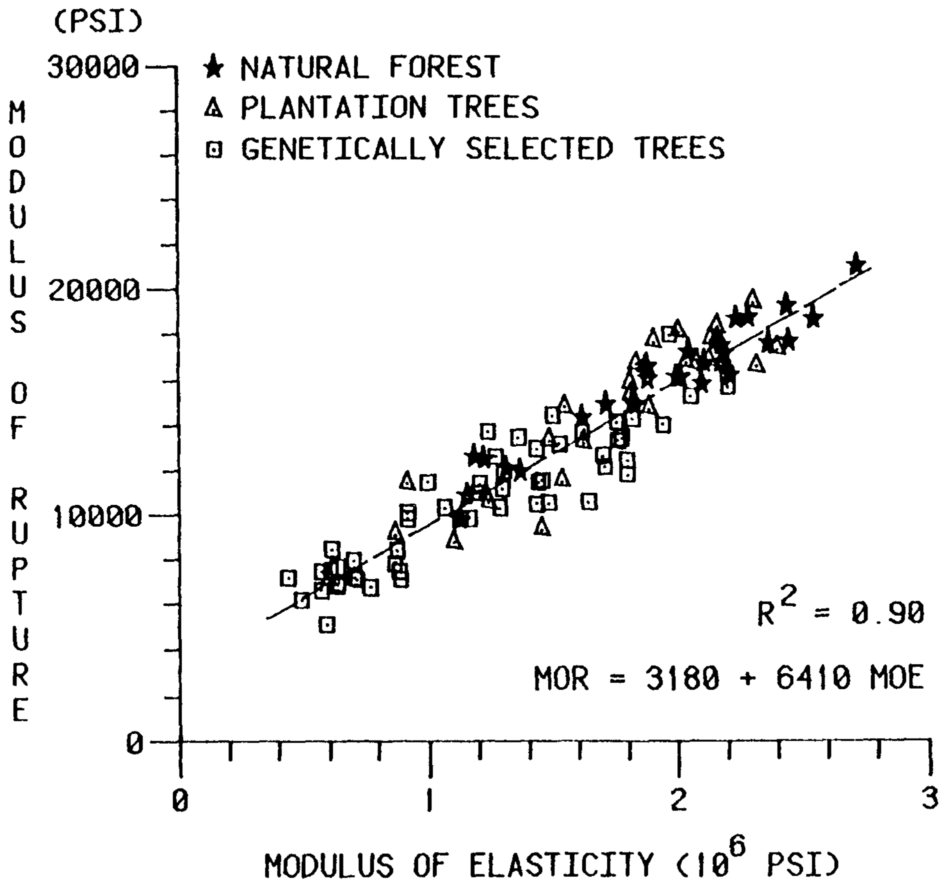

FIG. 8. Relation between modulus of rupture and modulus of elasticity.

CONCLUSIONS

The results emphasize the influence of the age at which the wood is formed (number of rings from the pith) on specific gravity and the bending properties. Growing loblolly pine trees faster provides a larger volume of juvenile wood with relatively lower specific gravity and correspondingly lower mechanical properties, and due allowance must be made for this in utilizing these trees. Fortunately, a fast growth rate does not appear to alter significantly the fundamental relations between the specific gravity and static bending properties of loblolly pine. Commercial volumes of wood with mechanical properties similar to that of current lumber should accordingly be obtainable, but the trees will have to be allowed to grow for more than two decades. Informed decisions on when to harvest fast-growing trees for various purposes will accordingly require knowledge of the properties of the wood at the various ages when it is formed.

REFERENCES

PEARSON, R. G., AND R. C. GILMORE. 1980. The effect of fast growth rate on the mechanical properties of loblolly pine. Forest Prod. J. 30(5):47–54.

PRICE, A. T. 1928. Mathematical discussion of on the structure of wood in relation to its elastic properties. Trans. Royal Society. Series A, 228:1–62.

TALBERT, J. T., J. B. JETT, AND R. L. BRYANT. 1983. Inheritance of wood specific gravity in an unimproved loblolly pine plantation: 20 years of results. Silvae Genetica (in press).

USDA FOREST PRODUCTS LABORATORY. 1974. Wood handbook. USDA Agric. Handbook No. 72 (rev.). Madison, WI.

ZOBEL, B. J. 1971. Genetic manipulation of wood of the southern pines, including chemical characteristics. Wood Sci. Tech. 5:255–271.

———, R. C. KELLISON, M. F. MATTHIAS, AND A. V. HATCHER. 1972. Wood density of the southern pines. North Carolina Agric. Exp. Sta. Tech. Bull. No. 208. Raleigh, NC.