ABSENCE OF GROWTH-WOOD PROPERTY CORRELATION IN TWENTY-SEVEN BLACK PINE SEED SOURCES[1]

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ABSTRACT

A black pine (*Pinus nigra* Arnold) plantation consisting of 27 seed sources in southwestern Lower Michigan furnished the study material. At age 10 from seed, a lateral branch from the south aspect of the top whorl of each tree was collected to study the genetic variation in specific gravity and tracheid length and to relate those with height growth. The between-seed source differences in branch-wood properties and height growth were all significant at the 1% level. However, the growth-wood property correlation was weak. Neither was the specific gravity-tracheid length correlation significant. This study confirmed the previous work that seed from the eastern species range should be used in the Lake States area. Use of faster growing material in the planting program does not cause the production of lower wood quality. It is further suggested that the two wood properties were controlled by different genes.

Keywords: *Pinus nigra*, specific gravity, tracheid length, height growth, provenance tests, genetic variation, wood quality.

INTRODUCTION

European black pine (*Pinus nigra* Arnold) has a wide natural range (35° to 48°N latitude and 6°W to 42°E longitude) in Mediterranean Europe. This species has been extensively planted outside its natural range. In the United States, it has been planted as an ornamental and along highways because of its resistance to salt injury. Some growers have started to market black pine as Christmas trees. Growth rate is comparable to native red pine (*Pinus resinosa* Ait.) in southwestern Michigan.

Although this exotic species has a potential for timber production, our knowledge is still limited and does not yet encourage large-scale commercial planting.

Specific gravity and tracheid length are important parameters that deserve more concern among foresters (Mitchell 1956, 1957). To breed a strain of rapid growing trees may not be sufficient unless accompanied by information on their wood qualities. The present study was designed to determine the genetic variability patterns in selected wood characteristics of black pine and to relate such patterns to growth trait.

MATERIAL AND METHODS

In 1958 seeds representing 25 native stands and two plantations were received from several research foresters in southern Europe. They were stored dry at 2–4 C until sowing.

The seeds were sown in the research nursery on the Michigan State University

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campus in spring 1959 following a randomized complete block design with four replications. Each plot consisted of one 1.2 m row. The rows ran at a right angle to the long axis of the nursery bed and were 18 cm apart, and they were later thinned to a density of 20 seedlings per 0.09 m^2 (per square foot). A fifth set of plots was broadcast sown to provide stock for permanent outplanting. The seedlings received the conventional nursery care characteristic of commercial practice in central Michigan.

The study plantation (MSFG 5-61) was one of four permanent outplantings established in spring 1961. It is located in Compartment 26-D, Kellogg Experiment Forest, 1.6 km north of Augusta, Kalamazoo County, in southwestern Michigan. A randomized complete block design was followed. In each of the 10 replications, there were 27 four-tree plots established with 2-0 seedlings planted 2.4 × 2.4 m apart.

The plantation site is of rolling moraine with sandy loam soils. It had not been used since 1948 and had a heavy sod of bluegrass. Woody vegetation was killed with 2,4,5-T during 1958–59. In May 1964 a directed spray of 5 kg of simazine and 19 liters of amino-triazole per ha was applied to 0.6-m strips containing trees.

I measured total height in August 1968 and again in July 1969 to the nearest 0.3 m. Mortality was also recorded.

Sampling for the study of wood properties was conducted in late August 1968. I collected a lateral branch from the south aspect of the topmost whorl of each tree. After debarking, I cut a 3-cm-long straight branchwood specimen from the basal end, removed the pith and split it longitudinally into two halves: one for specific gravity and the other for tracheid length study.

Specific gravity is defined as the ratio of oven-dry weight to the green volume and was determined by Smith's method (1954) using alcohol-benzene extractive-free material (Taras and Saucier 1967; Posey and Robinson 1969).

I macerated wood fibers in an equal mixture of glacial acetic acid and 30% hydrogen peroxide at 50–55 C for 72 h. After several changes with distilled water, the macerated fibers were stained with 1% Bismarck Brown Y aqueous solution overnight, then mounted on slides without dehydration (Echols 1969), and measured to the nearest mm with a Bausch and Lomb No. 2700 projector with approximately 80× magnification. Mean lengths of 20 tracheids were used as items for statistical analysis. Preliminary studies showed no statistically significant difference between mean length of samples of 20 and 30 tracheids based on 26 prepared slides ($t = 0.382$ with 25 df).

Plot means (seed source means) were used as items in all analyses. There were 26,9 and 234 degrees of freedom for seed sources, blocks and error, respectively, in analysis of variance and 25 degrees of freedom in the correlation analysis.

RESULTS AND DISCUSSION

The study plantation had the highest survival of any of the NC-99 (USDA funded project titled, "Improvement of Forest Trees through Selection and Breeding") black pine plantations established in 1961. Average mortality was 23% at the end of the first growing season. Dead trees of the first-year mortality were replaced. Mortality continued and totalled 10, 12, and 14% at the end of the

TABLE 1. *Wood and growth characteristics of different* Pinus nigra *provenances at age 10 (1968).*

Country	No. of seed sources	Specific gravity	Tracheid length mm	Tree height 1968	Tree height 1969
				cm	
Corsica	3	0.403	0.94*	152	232
Spain	2	0.398	0.93*	182	255
France	3	0.411	0.95*	193	279
Austria	1	0.407	0.94*	181	262
Yugoslavia	1	0.447*	0.96	202	269
Greece	13	0.408	0.97	181	261
Turkey	3	0.407	0.99	183	255
Crimea	1	0.415	0.99	214	292

* Differs significantly (5 percent level) from the mean of the Greek population.

1962, 1963, and 1968 growing seasons, respectively. At age 15 (1973), it was 17% of the original number of trees planted (Wheeler et al. 1976).

Approximately 60% of the total mortality occurred in the six seedlots characterized by mild climate: three from Corsica and three from the Greek Peloponnesian Peninsula. The number of dead Corsican trees was probably related to the amount of winter damage.

Growth had been satisfactory. As of the 11th year (1969), only one tree (MSFG 410 from France) in the plantation had flowered, producing three cones but no male flowers.

Differences in wood properties

Use of an increment core sample extracted at the breast height position has been a common approach for the evaluation of wood quality (Einspahr 1962; Mitchell 1958). However, in this study branchwood was used to reduce the amount of damage that might be inflicted on the test trees during the sampling process.

Table 1 shows branchwood specific gravity and tracheid length as affected by different seed origins. Branchwood data should provide adequate evidence for a study of geographic variation pattern, although their interpretation requires some degree of reservation. A separate experiment (Lee 1971) was conducted to establish a general branchwood-trunkwood correlation using 30 sample trees of the Turkish origin. Mean specific gravity of trunkwood was 0.392, that of branchwood, 0.352, differences being statistically significant ($t = 10.05$ with 29 df). The trunkwood (y) and branchwood (x) correlation was significant at the 1% level for specific gravity ($y = 0.068 + 0.929x$, $r = 0.76$) but not for tracheid length.

Because the study material was from a single plantation, it was not possible to analyze for possible seed source and plantation interactions. Working on 46-year-old Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco] of known origin, McKimmy (1966) found greater origin and plantation interactions on wood specific gravity than the genetic influences of the seed sources. If this is the case with European black pine, the complex of environmental factors would make it more difficult to predict the general performance of a given seed source at a given test site.

Specific gravity.—A single seed source (MSFG 415) from Yugoslavia had a higher specific gravity by far than those from the rest of the species range (Table 1). The specific gravity was relatively uniform for trees from Corsica, Spain, France, Austria, Greece, Turkey, and Crimea. Lack of close association between specific gravity and geographic regions was also found for Norway spruce [*Picea abies* (L.) Karst.] by Knudsen (1956). On the other hand, a close association was reported for loblolly pine (*Pinus taeda* L.) by Mitchell (1964) and Zobel et al. (1960); for slash pine (*Pinus elliottii* Engelm.) by Perry and Wang (1958) and Larson (1957); for eastern white pine (*Pinus strobus* L.) and red pine (*Pinus resinosa* Ait.) by Gilmore (1968) and Wahlgren et al. (1966); and for southern pine species by Wheeler and Mitchell (1962). The inconsistency may be due to differences in sampling technique and due to confounding effects of tree age with other factors (Zobel and McElwee 1958).

Overall mean branchwood specific gravity was 0.409, comparable to the native U.S. southern pine species. The range in seed source means varied from 0.319 to 0.493, a difference of 55%. The between-tree range was from 0.255 to 0.548, a difference of 115%. They were, respectively, 15 and 72% of the overall mean specific gravity. The greater between-tree variation was expected because it was also the case with southern pine (Mitchell 1964; Wakeley 1969) and Monterey pine (*Pinus radiata* D. Don) reported by Dadswell et al. (1961). The larger the variation, the faster and more efficiently improvement can be made through selection.

A separate set of analyses based on seed source means (plot means) was conducted to correlate 1968 height with branchwood specific gravity. The relationship was weak (r = 0.367 with 25 df). The growth-specific gravity correlation was also found to be nil for comparable age of loblolly pine (Zobel and McElwee 1958). In a study of slash pine, there was a 0.003 specific gravity difference that was statistically significant between average growing trees and those growing 2.67 times as fast as the former (Perry and Wang 1958). A weak relation between specific gravity and growth was also established for jack pine (*Pinus banksiana* Lamb.) by Spurr and Hsiung (1954). These facts may imply that selection of faster growing individuals does not cause selection of lower specific gravity wood for European black pine.

Tracheid length.—There were significant (1% level) between-seed source differences in branchwood tracheid length in black pine (Table 1). A steady increase in tracheid length from west to east in the species range was apparent. Trees from the western range had below average tracheid length, while those from the eastern range were characterized by average or above average tracheid length. The geographic pattern in this wood property was also reported for other pine species. The latitude of Scotch pine (*Pinus sylvestris* L.) seed sources was significantly correlated with tracheid length (Echols 1958). Loblolly pine sampled from seven southern states followed a geographic pattern (Zobel et al. 1960).

Overall mean branchwood tracheid length was 0.96 mm for black pine. The range in seed source means varied from 0.83 to 1.07 mm, a difference of 29%. The between-tree range was from 0.83 to 1.13 mm, a difference of 36%. They were, respectively, 25 and 31% of the overall mean tracheid length. Again, the greater tree-to-tree variation was no exception in this wood property.

Using seed source means as items, the 1968 height-branchwood tracheid length relation was found to be nil. Only 6% of the total variation was accounted for by height growth. Neither was there a tracheid length-specific gravity relationship (rank correlation coefficient = −0.011). Because the weak correlation was also the case with other pine species (Jackson and Strickland 1962), it seems likely that the two wood characteristics could be controlled by different genes.

Growth differences

Early measurements on black pine were summarized by Wright and Bull (1962). They were able to identify two ecotypes: winter-injured Corsican and healthy non-Corsican. Lee (1968) made a detailed study on nineteen anatomical characters of the needles and foliar mineral content as well as differences in growth rate, branch angle, and winter hardiness between 1963 and 1965 when the trees were 5 to 7 years old from seed. He reported that all Corsican seed sources suffered heavy winter damage and those from Spain and France received moderate injury. A similar trend was reported by a German researcher (Roehrig 1966). The information on growth characteristics is summarized in Table 1.

Growth rate.—A remarkable change in growth performance occurred to Corsican trees. In 1965 (7 years old from seed), they were the only ones whose growth rate was significantly slower than the mean of the Greek population. This growth pattern showed a change in the 1968–69 measurements; they were no longer significantly different from the several Greek seed sources. After their ninth year, Corsican trees seemed to become hardier and a few individuals even grew faster than any other trees in the study plantation.

As of 1969, the total height differences were not large in spite of the fact that considerable climatic differences exist throughout the species range. This confirmed Roehrig's (1966) early observation on eighteen seed sources in each of his four provenance study plantations established in Germany in 1956 and 1957.

Most plantations in the United States are believed to be of Austrian origin. Before its seventh year, the single Austrian seed source (MSFG 423) grew slowest among healthy non-Corsican sources. The growth rate has been average since then.

There was considerable variation (statistically significant at the 5% level) within regions, even among nearby seed sources. For example, seed source 425 from Macedonia, northeastern Greece, was 18% taller than seed source 424 from a nearby Greek locality.

A slight geographic pattern was evident among the Greek seed sources. Three from the Peloponnesian Peninsula, southern Greece, have been below average in growth rate since 1963 (5 years old), with 1969 heights of 219, 248 and 239 cm.

The correlation coefficients were 0.945, 0.885, 0.720, and 0.664, respectively, when the 1963 height was correlated with the 1964, 1965, 1968, and 1969 heights. Although they were all statistically significant at the 1% level, they tended to decrease consistently with time. This may suggest that changes in relative height can be expected in the future.

At age 15 (1973), the same plantation was revisited and strong age-age correlations were reconfirmed (Wheeler et al. 1976). Above-average seed sources at age 5 stayed above average in height growth. Because of the outbreak of serious disease epidemics in early 1970's, it was hypothesized that height growth might depend more on inherent resistance than upon inherent growth rate. Seed sources from the eastern half of the species range were found more insect- and disease-resistant than those from the western species range.

CONCLUSION

The study material from a Michigan provenance test plantation consisting of 27 geographic seed sources revealed that European black pine was a genetically variable species in branchwood specific gravity, tracheid length, and height growth. Although the between-seed source differences in those characteristics were significant at the 1% level, there were no correlations among them. Furthermore, the present study could not establish any close association between specific gravity and tracheid length.

On the basis of the results of the present study and recent work by Wheeler et al. (1976), seed from the eastern species range should be recommended as planting material in the Lake States area because the trees are winter hardy, fast growing, insect and disease resistant and have better wood properties.

REFERENCES

DADSWELL, H. E., J. M. FIELDING, J. W. P. NICHOLLS, AND A. G. BROWN. 1961. Tree-to-tree variation and the growth heritability of wood characteristics of *Pinus radiata*. Tappi 44:174–179.

ECHOLS, R. M. 1958. Variation in tracheid length and wood density in geographic races of Scotch pine. Yale Univ. School For. Bull. No. 64:1–52.

———. 1969. Permanent slides of stained wood fibers without dehydration or cover glasses. Forest Sci. 15:411.

EINSPAHR, D. W. 1962. Evaluation of wood and pulp properties using increment core samples. Amer. Forester 49:17–21.

GILMORE, A. R. 1968. Geographic variation in specific gravity of white pine and red pine in Illinois. For. Prod. J. 18:49–51.

JACKSON, L. W. R., AND R. K. STRICKLAND. 1962. Geographic variation in tracheid length and wood density of loblolly pine. Ga. For. Res. Council Res. Paper No. 8, 4 pp.

KNUDSEN, M. V. 1956. A comparative study of some technological properties of Norway spruce in a provenance test (Docum.) 12th Congr. Int. Union For. Res. Organ. Oxford No. IUFRO 56/41/2, 7 pp.

LARSON, P. R. 1957. Effect of environment on the percentage of summerwood and specific gravity of slash pine. Ph.D. Dissertation, Yale Univ. School For. Bull. No. 63, 87 pp.

LEE, C. H. 1968. Geographic variation in European black pine. Silvae Genet. 17:165–172.

———. 1971. Trunkwood-branchwood specific gravity and tracheid length relationship in *Pinus nigra*. For. Sci. 17:62–63.

MCKIMMY, M. D. 1966. A variation and heritability study of wood specific gravity in 46-year-old Douglas-fir from known seed sources. Tappi 49:542–549.

MITCHELL, H. L. 1956. Breeding for high-quality wood. USFS For. Prod. Lab. Rep. No. 2050, 15 pp.

———. 1957. Applying forest tree improvement practices in the Lake States: Production of quality wood. USFS For. Prod. Lab. Rep. No. 2103, 7 pp.

———. 1958. Wood quality evaluation from increment cores. Tappi 41:150–156.

———. 1964. Patterns of variation in specific gravity of southern pines and other coniferous species. Tappi 47:276–283.

PERRY, T. O., AND C. W. WANG. 1958. Variation in the specific gravity of slash pine wood and its genetic and silvicultural implications. Tappi 41:178–180.

POSEY, C. E., AND D. W. ROBINSON. 1969. Extractives of shortleaf pine: An analysis of contributing factors and relationships. Tappi 52:110–115.

ROEHRIG, E. VON. 1966. Die Schwarzkiefer und ihre Formen. II. Erste Ergebnisse von Provenienzversuchen. Silvae Genet. 15:21–26.

SMITH, D. M. 1954. Maximum moisture content method for determining specific gravity of small wood specimens. USFS For. Prod. Lab. Rep. No. 2014, 8 pp.

SPURR, S. H., AND W. Y. HSIUNG. 1954. Growth rate and specific gravity in conifers. J. For. 52:191–200.

TARAS, M. A., AND J. R. SAUCIER. 1967. Influence of extractives on specific gravity of southern pine. For. Prod. J. 17:97–99.

WAHLGREN, H. E., AND D. L. FASSNACHT. 1959. Estimating tree specific gravity from a single increment core. USFS For. Prod. Lab. Rep. No. 2146, 9 pp.

———, A. C. HART, AND R. R. MAEGLIN. 1966. Estimating tree specific gravity of Maine conifers. USFS For. Prod. Lab. Res. Pap. FPL 61. 22 pp.

WAKELEY, P. C. 1969. Effects of evolution on southern pine wood. For. Prod. J. 19:16–20.

WHEELER, N. C., H. B. KRIEBEL, C. H. LEE, R. A. READ, AND J. W. WRIGHT. 1976. 15-year performance of European black pine in provenance tests in North Central United States. Silvae Genet. 25:1–6.

———, AND H. L. MITCHELL. 1962. Specific gravity variation in Mississippi pines. USFS For. Prod. Lab. Rep. No. 2250, 10 pp.

WRIGHT, J. W. AND W. I. BULL. 1962. Geographic variation in European black pine: Two-year results. For. Sci. 8:32–42.

ZOBEL, F. J., AND R. L. MCELWEE. 1958. Natural variation in wood specific gravity of loblolly pine, and an analysis of contribution factors. Tappi 41:158–161.

———, E. THORBJORNSEN, AND F. HENSON. 1960. Geographic, site and individual tree variation in wood properties of loblolly pine. Silvae Genet. 9:149–158.