WOOD PROPERTIES OF RED SPRUCE IN MAINE ON SOILS OF THREE DRAINAGE CLASSES

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ABSTRACT

Dominant red spruce (*Picea rubens* Sarg.), average age 55 years at breast height, were sampled on soils of three drainage classes in north central Maine. Specific gravity, radial growth rate, alcohol/benzene soluble extractables content, and lignin content were determined from 12-mm increment cores.

Mean specific gravity of trees on the poorly drained soil was 0.03 higher (8%) than that of trees on the somewhat poorly drained soil and 0.02 higher (5%) than specific gravity of trees on the combination of moderately well and well-drained soils. Growth rate was 1.5 mm/yr on both the somewhat poorly drained soil and on the moderately well and well-drained soils. Growth rate on the poorly drained soil was 1.3 mm/yr. Specific gravity decreased as growth rate increased, although the correlation was weak ($r = -0.24$). Extractables and lignin contents did not differ among drainage classes.

Keywords: Red spruce, specific gravity, lignin, alcohol/benzene soluble extractables, soil drainage class.

INTRODUCTION

The forest industries of Maine use more than six million cords of wood annually (Field 1980). Much of this wood is red spruce (*Picea rubens* Sarg.) and balsam fir [*Abies balsamea* (L.) Mill.], with red spruce being the preferred species. Red spruce is used primarily for pulp, and to a lesser extent for structural lumber and board products.

Maine's spruce-fir forest occupies approximately eight million acres, 2.5 million of which are soils of the Chesuncook catena.[1] Existing mature stands on these soils will be an important source of wood fiber beyond the year 2000. In addition, intensive management practices have been initiated in many young spruce-fir stands on these soils.

This paper reports the results of a study of the specific gravity (SG), radial growth, extractables, and lignin content of red spruce on the major soils of the Chesuncook catena. Also presented is the relationship between SG and growth rate. It is hoped that this information will be of benefit as the forest industries strive to use existing wood supplies more efficiently, while putting intensive management strategies into effect.

PROCEDURE

Field sampling

Five stands were selected on each of three soil series of the Chesuncook catena. The soils have all developed in compact basal till and differ in drainage charac-

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[1] Soil series that have originated from the same parent material but differ primarily in drainage characteristics.

teristics. The soils are: 1) moderately well (MWD) and well-drained (WD) (Chesuncook and Elliottsville series combined—coarse loamy, mixed, frigid Typic Haplorthods); 2) somewhat poorly drained (SPD) (Telos series—coarse loamy, mixed, frigid Aquic Haplorthod); and 3) poorly drained (PD) (Monarda series—coarse loamy, mixed, frigid Aeric Haplaquept). Although different series, MWD and WD soils were considered as one because of the difficulty encountered in locating stands of sufficient extent on these soils and because of the similarity between these soils.

Increment cores (12 mm) were taken at breast height from ten dominant red spruce in each stand. Sample trees were selected from among trees with good form and uniform crowns. Leaning, crooked, and otherwise deformed trees were avoided because of the possible effect of poor form on wood properties. The average age of sample trees from each soil was approximately 55 years at breast height, being 54, 55, and 57 years for PD, SPD, and MWD and WD soils, respectively. The ranges in age were 40–68 years, 47–75 years, and 46–73 years. An attempt was made to keep the ages of the sample trees as uniform as possible to reduce any differences in SG that might result from differences in age.

Laboratory work

The first ten growth rings were removed from each core, and the length of the core (ring 11 to the bark) was measured to the nearest 0.1 mm using micrometer calipers. Mean annual growth rate for ring 11 to the bark was determined. The first ten years of growth were removed because the pith was off center in most cores. Specific gravity for each core from ring 11 to the bark was determined using the maximum moisture content method (Smith 1954).

After SG was determined, each core was ground in a Wiley mill so as to pass through a 40-mesh screen. All cores from a given stand were combined into a composite sample, providing five composite samples for each soil drainage class. Alcohol/benzene soluble extractables were determined according to TAPPI Standard T-12 and lignin content according to TAPPI Standard T-222. Analyses were performed on three subsamples from each composite sample.

Statistical analysis

A nested analysis of variance was used to test for significant differences in SG, growth rate, extractables content, and lignin content of wood among soils and among stands within soils. Percents of extractables and lignin were subjected to an arcsine transformation prior to analysis. Duncan's multiple range test at $P = 0.05$ was used to analyze for differences where appropriate. The simple correlation coefficient (r) for SG vs. growth rate and the coefficient of determination (r^2) were calculated.

RESULTS AND DISCUSSION

Specific gravity

There were significant ($P \leq 0.05$) differences in SG of wood from trees on the different soils and highly significant ($P \leq 0.01$) differences among stands within soils (Table 1). The highest SG, 0.39, was for trees on the PD soil (Table 1) and was significantly greater than SG for trees on the SPD, and MWD and WD soils.

TABLE 1. *Specific gravity (mean and range) and analysis of variance table of dominant red spruce on soils of three drainage classes (ten trees sampled per stand).*

Stand	Drainage class: Moderately well and well	Somewhat poorly	Poorly
1	0.36 (0.34–0.40)	0.36 (0.34–0.38)	0.39 (0.35–0.42)
2	0.38 (0.33–0.42)	0.39 (0.36–0.42)	0.37 (0.36–0.42)
3	0.36 (0.32–0.41)	0.37 (0.34–0.41)	0.40 (0.35–0.46)
4	0.38 (0.35–0.40)	0.36 (0.34–0.40)	0.39 (0.35–0.46)
5	0.36 (0.34–0.40)	0.35 (0.33–0.38)	0.38 (0.37–0.40)
Avg.	0.37 (0.33–0.41)	0.36 (0.34–0.40)	0.39 (0.37–0.43)

Analysis of variance table

Source	df	Sum of squares	Mean square	F	$P > F$
Soils	2	0.01418005	0.00709003	4.96	0.0269
Stands within soils	12	0.01714612	0.00142884	2.68	0.0029
Error	135	0.07209290	0.00053402	—	—
Total	149	0.10341907			

The work of Wahlgren et al. (1968) suggests that whole tree SG would be somewhat lower than these values.

It appears that differences in SG were caused by a factor other than age. Trees on the PD soil may produce slightly more latewood as a result of more available soil moisture later in the growing season. Larson (1957) reported that differences in latewood percentage accounted for more than 60% of the total variation in SG of slash pine (*Pinus elliottii* Engelm. var. *elliottii*). On the basis of values of earlywood and latewood SG for spruce from Kollmann and Côté (1968), a difference in SG of the magnitude observed here could be caused by a decrease in earlywood and an increase in latewood of only 4 or 5%. The difference in SG may also result from a difference in number of cells per unit area and/or average tangential wall thickness. Quirk (1984) found that these two variables together

TABLE 2. *Annual radial growth rate (mean and range) and analysis of variance table of dominant red spruce on soils of three drainage classes (ten trees sampled per stand).*

Stand	Drainage class: Moderately well and well	Somewhat poorly	Poorly
		mm	
1	1.8 (1.4–2.6)	1.5 (1.2–1.9)	1.3 (1.1–1.6)
2	1.6 (1.3–2.0)	1.6 (1.1–2.0)	1.4 (1.2–1.7)
3	1.3 (0.9–1.5)	1.6 (1.2–2.1)	1.2 (0.9–1.6)
4	1.2 (1.0–1.4)	1.3 (1.2–1.4)	1.2 (1.1–1.4)
5	1.7 (1.4–2.0)	1.6 (1.2–2.0)	1.4 (1.0–1.8)
Avg.	1.5 (1.2–1.9)	1.5 (1.2–1.9)	1.3 (1.1–1.6)

Analysis of variance table

Source	df	Sum of squares	Mean square	F	$P > F$
Soils	2	1.24156133	0.62078067	2.33	0.1369
Stands within soils	12	3.20023600	0.26668633	5.12	0.0001
Error	135	7.03007000	0.05207459	—	—
Total	149	11.67186733			

accounted for 90 to 99% of SG variation in both earlywood and latewood of Douglas fir [*Pseudotsuga menziesii* (Mirb.) Franco].

Although not large in absolute terms, the difference in SG observed here may be important technologically. A SG difference of 0.03 may result in a difference in kraft pulp yield of as much as 8%. In addition to yield, numerous pulp properties are related to SG (Barefoot et al. 1972). Beating time, burst factor, and breaking length all decrease as SG increases; tear factor increases with increasing SG. Modulus of rupture and modulus of elasticity of lumber increase as SG increases. On the basis of relationships presented by Wangaard (1950) and Bodig and Jayne (1982), a change in SG from 0.39 to 0.36 means a difference of about 10% in both of these mechanical properties. The differences in SG that occur among trees on the three soils raise the question as to whether separating the wood in the woodyard based on the soil from which it was harvested should be considered.

There was considerable variation in SG among individual trees in each stand (Table 1). Because the SG of many conifers is heritable (Panshin and deZeeuw 1980), it should be possible to increase SG of red spruce through a tree improvement program. However, at present red spruce is not one of the species favored for planting in Maine.

Growth rate

Differences in mean radial growth rate (ring 11 to the bark) of trees among soils were not significant, but differences among stands within soils were highly significant (Table 2). The slowest growth rate, 1.3 mm per year, was for trees on the PD soil. The growth rate of trees on the other soils was 1.5 mm per year. Although differences among soils were not significant, the trend observed agrees with the findings of Schiltz and Grisi (1980) and supports their conclusion that intensive management efforts should be concentrated on the better drained soils where the potential for rapid growth is greater.

Growth of trees on PD soils is usually slower than growth of trees on better drained soils, largely because of less favorable soil aeration conditions that tend to retard root growth. Also, PD soils remain colder longer into the growing season than better drained soils, because they remain wetter longer. Because water has a high specific heat, PD soils warm more slowly than better drained soils. These lower soil temperatures lead to slower rates of root growth and metabolic activity, which are reflected in slower radial growth.

Specific gravity vs. growth rate

The overall correlation coefficient for SG vs. growth rate, −0.24, was highly significant. However, although the correlation coefficient was highly significant, growth rate accounted for only 5.7% of the variation in SG. Correlation coefficients for the individual soils ranged from −0.09 for the SPD to −0.22 for the PD soil, and although none was significant, they do suggest that a very weak relationship of decreasing SG with increasing growth rate may exist regardless of soil drainage class.

The correlation between SG and growth rate is frequently weak and in some instances nonexistent (Larson 1957; Bendtsen 1978). However, numerous investigators working with spruces, including Aldridge and Hudson (1958), Keith

(1961), Chang and Kennedy (1968), Brazier (1970), and Taylor et al. (1982) have reported a negative correlation between SG and growth rate. Wolcott (1985), however, found no reduction in SG of red spruce following thinning in a 50-year-old stand even though radial growth rate increased three to four times in some trees.

Extractables

Alcohol/benzene soluble extractables contents ranged from 1.92% for trees on the MWD and WD soils to 2.05% for trees on the PD soil, with an overall average of 1.99%. Differences among means for trees on the three soils were not significant, nor were the differences among stands within soils. Differences among stands within soils ranged from 0.33% on the PD soil to 0.85% on the MWD and WD soils. That extractables were only slightly greater in trees on the PD soil indicates that extractables were not responsible for the higher mean SG of those trees.

Lignin

Lignin content averaged 26.85% and did not differ significantly among trees on the different soils or among stands within soils. The highest lignin content, 27.01%, occurred in trees on the MWD and WD soils and the lowest lignin content, 26.72%, in trees on the PD soil. The range among stands within soils was from 0.81% on the MWD and WD soils to 0.33% on the PD soil.

CONCLUSIONS

The following conclusions are based on a limited sample of increment cores from dominant red spruce on soils of different drainage classes. It is possible that some may change as more data become available.

1. Mean specific gravity on the poorly drained soil was significantly greater than mean specific gravity on the somewhat poorly drained soil, and mean specific gravity on the moderately well and well drained soils combined.
2. Differences in mean radial growth rates among soils were not significant, although growth was slowest on the poorly drained soil.
3. The overall correlation coefficient for specific gravity vs. radial growth rate was negative and highly significant; it was small (−0.24), however. Correlation coefficients for individual soils were also negative but not significant.
4. Differences in mean lignin contents among soils were not significant; differences in mean extractables contents were also not significant.

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