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CORRELATION BETWEEN STEM GROWTH AND DENSITY IN YOUNG INTERIOR SPRUCE

by

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NOTICE

SUMMARY

The phenotypic correlation between wood density and stem growth (tree height and diameter) was examined in young interior spruce. The sample trees represented 40 half-sib families in two progeny test sites in British Columbia. In general, the relationship was found to be negative and weak. There were individual trees and families that showed fast growth and above-average wood density. If genetic correlations are equal to or weaker than the phenotypic correlations, and if the correlations persist in the mature trees, it would be possible to select individual trees and families for fast growth without reducing wood density.

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1.0 INTRODUCTION

Density is one of the most important indicators of wood quality. Its relationship to a number of wood properties has been widely studied and documented (De Montmorency 1965; Einspahr *et al.* 1969; Brazier 1973; Doucet *et al.* 1983; Armstrong *et al.* 1984) For example, many mechanical and strength properties of wood are a function of wood density (Armstrong *et al.* 1984). For the pulp industry where products are sold on a weight basis and pulp yield is a major consideration, wood density is an important characteristic of the raw material.

In British Columbia tree improvement programs, primary interest centers on growth rate as a selection trait for the major commercial species of the province, but wood density will also be considered in second generation selections (British Columbia Ministry of Forests 1988). Wood density is gaining interest in other parts of Canada as well (Roddy 1986; Mullin 1987; Simpson 1988).

The relationship between wood density and stem growth in white spruce (*Picea glauca* (Moench) Voss) has been shown to be negative (Chang and Kennedy 1967; Corriveau *et al.* 1990). Taylor *et al.* (1982) found this relationship to be negative or not different from zero in the outer rings of wild mature trees in Alberta. Roddy (1986) similarly concluded that this relationship was minimally negative and nearly zero in 28 white spruce parent trees from Saskatchewan. It seems that the growth rate-wood density relationship in white spruce is not entirely clear and further assessment is needed.

In 1968, the British Columbia Ministry of Forests initiated a tree improvement program for interior spruce ((*P.glauca* (Moench) Voss) and (*P.engelmannii* Parry)), and selection for genetic improvement is underway. Open-pollinated progeny trials were established in 1973 (Kiss and Yeh, 1988). The trees were measured for height and diameter, but not for wood density, at age 15. Selection for growth rate alone could adversely affect wood density and reduce the wood quality of the future trees. The trees in the progeny tests are now large enough to be evaluated for wood density. It is important to assess the wood density-growth rate relationship at this stage if wood density is to be considered in the selection process.

Forintek initiated a collaborative effort with Dr. Alvin Yanchuck of the B.C. Ministry of Forests and with Dr. Don Lester of the University of British Columbia to evaluate the wood density of the interior spruce progeny trials (Kiss and Yeh 1988). The Ministry provided the increment core samples and data on diameter and height of the trees at age 15. Dr. Lester will analyze the extent of genetic relationship between ring density components (earlywood and latewood density) and ring width.

2.0 OBJECTIVE

The study objective was to assess the variation in wood density of 40 families of interior spruce, and to examine the correlations between wood density and the stem growth (diameter and height) of the trees.

3.0 STAFF

Josefina Gonzalez	Research Scientist
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4.0 MATERIALS AND METHODS

Samples for this study were obtained from two of three sites that were established in 1973 with progenies from open-pollinated seeds collected from 174 interior spruce (Kiss and Yeh 1988). The sites were established according to a randomized complete block design with 10-tree row plots. Ten blocks were installed per site. Site descriptions are presented in Table 1.

Thirty of the 174 families were sampled for this study. In addition, samples were taken from 10 families previously selected for a parent-progeny study (Lester 1990). Two trees per plot were sampled in the first seven blocks at each of the two sites, making a total of 28 trees per family. The exception was family number 103 from which only 18 trees were sampled because there were fewer trees available. Trees that were sampled had a diameter of at least 3.0 cm at a height of 30 cm from the ground. Smaller trees were excluded so that potential damage to them could be avoided. These trees were few in number, however, and any bias resulting from excluding them should be minimal.

A single bark-to-bark increment core was extracted from each tree at 30 cm above the ground from the same cardinal direction. The cores generally included the pith and were screened for knots and abnormalities such as severe compression wood and resin pockets. This resulted in some cores being discarded and excluded from the analysis. A total of 1026 trees were analyzed. The number of trees per family included in the analysis is given in Table 2.

The cores were debarked and analyzed for density by the maximum moisture content method (Smith 1954). A second determination using direct X-ray densitometry (Josza *et al.* 1986) was carried out on the 10 families selected for parent-progeny study, to obtain a radial profile of the annual ring width earlywood and latewood density. These data, together with those obtained earlier on the parent trees, will be the subject of a separate report on the genetic components in earlywood and latewood density of interior spruce (Lester 1990).

Tree heights and outside-bark diameter at breast height (OBDBH) were available from measurements made 2 years earlier by the British Columbia Ministry of Forests. Inside-bark diameter was measured on debarked cores with a caliper calibrated to the nearest 0.05 of a millimeter.

5.0 RESULTS AND DISCUSSION

5.1 WOOD DENSITY, OBDBH, AND HEIGHT

The core samples examined consisted of 12-14 growth rings from the pith. In white spruce, juvenile wood has been reported to consist of the first 10-25 growth rings from the pith (Taylor *et al.* 1982; Jozsa and Kellogg 1986) based on wood density. Using wood density as a criterion, the cores in the present study were considered to be juvenile wood.

Table 2 presents the list of families sampled, identified by number, and ranked by mean density. Family mean and standard deviation for density, height, and OBDBH for the combined sites are also given.

The mean wood densities for the two sites were not significantly different. The pooled data gave an overall mean density of 407 kg/m^3, with a range of 310 - 523 kg/m^3 and a coefficient of variation of 7.6%. The family mean for the combined sites ranged from 384 - 443 kg/m^3. These values appear high compared to an average of 328 kg/m^3 previously reported (Gonzalez 1990) for interior spruce parent trees. However, that value was determined on mature wood from the outer half of breast height cores, and mature wood has been shown to have lower wood density than juvenile wood in white spruce (Jozsa and Kellogg 1986; Roddy 1986; Corriveau *et al.* 1987). This is the result of a density profile that starts high near the pith, declines rapidly in the first 8 - 10 years of growth, then levels out in the mature wood (Jozsa and Kellogg 1986) (Figure 1). The density profile of the juvenile wood in the present study was consistent with this trend (Figure 2).

The overall mean height and OBDBH of the trees were 3.2 m and 44.4 mm, respectively. The coefficient of variation was 24.4% for height and 33.9% for diameter, which are much higher than that for wood density. The higher variations in height and diameter provide greater potential for genetic gain in height and diameter.

5.2 PHENOTYPIC CORRELATIONS BETWEEN WOOD DENSITY, DIAMETER (OBDBH), AND HEIGHT

The correlation coefficients shown in Tables 3 and 4 indicate negative relationships between wood density and tree growth (diameter and height). The overall and interfamily relationships were weak, but within-family relationships were moderately strong ($r \leq -0.5$) in more than a third of the families. Two families (Nos. 3 and 6) were high in both density and growth. For example, family No. 3 ranked first in diameter, eighth in density, and eleventh in height. Family No. 6 ranked ninth in diameter, third in density, and fourth in height. Both families were in the top 25% of the list for each trait (Table 5). Seven families showed equal or higher than average density, diameter, and height.

In a study of 19-year-old white spruce progeny trials in Quebec (Corriveau *et al.* 1990), the phenotypic correlation between wood density and diameter was also found to be negative and weak (-0.32) and nearly equal to the genetic correlation (-0.36). While the phenotypic correlations obtained in the present study are negative and weak, the genetic correlations obtained in a preliminary analysis of the same data (Yanchuck 1990) were even weaker (nearly zero in both cases: between wood density and OBDBH, and between wood density and height). If genetic correlations are equal to or weaker than the phenotypic correlations, it would be possible to achieve genetic gain in stem growth with no adverse effect on wood density. This would be possible through appropriate selection of individual trees and families, provided the correlations persist in the mature trees. The correlations could be expected to remain in the mature trees on the basis of a study by Corriveau *et al.* (1987) who found a significant correlation between juvenile and mature wood densities in white spruce.

Diameter and height were strongly correlated at all levels (Tables 3 and 4) and no attempt was made to examine their combined effect on density. Correlation with wood density was weaker for height than for diameter.

The diameters (OBDBH) used in the above correlations were taken at breast height and included bark. Their values were therefore checked against the actual diameters of the debarked core samples taken at 30 cm above ground. A total of 309 cores from six blocks (three from each site) were used for this purpose. Correlation between the two diameters was found to be high (r=0.91).

6.0 CONCLUSIONS

1. In general, wood density showed negative and weak phenotypic correlations with stem diameter and height. There were individual trees and families that showed fast growth and above-average wood density. Since the genetic correlations were weaker (nearly zero), and if these relationships persist in the mature wood, individual trees and families could be selected for fast growth, without reducing wood density.

2. Diameter and height are strongly and positively correlated. Density correlated more strongly with diameter than with height.

3. Wood density variation is much lower than that for diameter and height.

4. Wood density in interior spruce is initially high near the pith and declines rapidly during the first 8 - 10 growth rings from the pith, after which it tends to level out.

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TABLE 1. Description of test plantation for interior spruce[a]

Site	Longitude (°N)	Latitude (°W)	Elevation (m)	Soil description	Site preparation
Red Rock	122.43	53.46	610	Alluvial gravelly loam	disced and root-picked
Quesnel	122.14	52.59	915	Clay and silty loam	Prescribed burning

[a] Kiss and Yeh (1988).

TABLE 2. **Mean values and standard deviations (SD) for wood density, height, and outside-bark diameter at breast height (OBDBH) of 40 families of interior spruce from the combined sites of Red Rock and Quesnel. Values are arranged in increasing order of magnitude of wood density.**

Family No.	No. of trees sampled	Wood density (kg/m³)	SD	Height (m)	SD	Diameter at breast height (mm)	SD
22	27	384	33	3.49	0.88	50.0	18.5
87	26	389	25	3.77	0.85	52.1	14.1
86	26	390	32	3.14	0.74	44.2	17.5
168	24	391	22	2.82	0.77	38.3	13.5
82	27	391	27	2.96	0.71	44.7	17.1
1	28	391	22	3.24	0.84	45.5	15.1
17	27	394	22	3.54	0.75	48.4	12.0
16	26	394	24	3.50	0.82	47.0	14.9
106	25	394	32	2.85	0.67	40.1	15.9
158	24	395	29	3.21	0.90	43.8	17.7
85	27	397	27	3.31	0.85	43.6	14.8
36	25	399	30	2.89	0.89	38.4	13.3
160	23	400	36	3.37	0.74	50.5	19.9
115	25	402	24	3.16	0.59	45.7	15.0
161	28	402	26	3.61	0.76	49.0	15.6
40	22	403	31	3.47	0.59	48.9	11.1
26	28	404	31	3.38	0.77	46.1	15.2
142	24	404	32	3.08	0.62	43.7	12.5
9	26	404	22	3.40	0.73	48.6	12.2
27	26	405	28	3.38	0.55	43.9	12.8
143	27	405	21	3.42	0.89	45.1	12.3
153	25	406	35	2.80	0.71	41.8	13.2
39	28	407	31	3.24	0.60	45.5	14.0
170	27	407	26	2.97	0.58	40.2	13.7
84	25	408	29	3.41	0.69	47.5	16.1
163	26	408	26	2.97	0.67	40.3	13.7
156	25	410	30	2.76	0.72	40.9	15.0
149	23	412	28	2.71	0.61	35.5	11.9
21	28	414	27	3.37	0.68	47.1	12.1
122	28	414	27	3.10	0.71	45.5	12.8
80	26	415	32	3.27	0.58	47.3	11.5
103	17	415	33	3.15	0.59	46.0	13.5
3	23	416	37	3.38	0.88	52.9	22.8
13	28	417	26	3.17	0.78	42.6	15.0
25	26	419	27	3.17	0.71	44.0	13.4
41	27	419	30	2.75	0.83	37.2	16.8
15	24	424	28	3.29	0.94	45.2	15.5
6	28	429	29	3.53	0.80	48.2	14.3
90	26	441	28	2.60	0.62	33.2	11.4
104	25	443	31	2.89	0.60	38.0	11.6
	Avg =	407	Avg =	3.2	Avg =	44.4	
	% CV =	7.6	% CV =	24.4	% CV =	33.9	

TABLE 3. Phenotypic correlations between wood density and stem growth (diameter and height) in interior spruce progeny tests

	GENERAL CORRELATIONS	
	Diameter (OBDBH)	Height
Wood density	-0.47 (p=0.0001)	-0.40 (p=0.0001)
Diameter (OBDBH)		0.85 (p=0.0001)

	INTERFAMILY CORRELATIONS	
	Diameter (OBDBH)	Height
Wood Density	-0.35 (p=0.0287)	-0.31 (p=0.0515)
Diameter (OBDBH)		0.90 (p=0.0001)

TABLE 4. Phenotypic correlations between density, diameter (OBDBH), and tree height within families of young interior spruce.

Family No.	No. of trees sampled	Density vs diameter	Density vs height	Diameter vs height
1	28	-.43	-.39	0.90
3	23	-.50	-.32	0.90
6	28	-.60	-.39	0.89
9	26	-.73	-.56	0.80
13	28	-.55	-.46	0.92
15	24	-.60	-.57	0.88
16	26	-.61	-.62	0.84
17	26	-.53	-.30	0.85
21	28	-.49	-.44	0.86
22	27	-.67	-.71	0.85
25	26	-.23	-.14	0.86
26	28	-.49	-.41	0.93
27	26	-.47	-.42	0.84
36	25	-.66	-.63	0.91
39	28	-.51	-.28	0.87
40	22	-.56	-.33	0.71
41	27	+.16	+.13	0.93
80	26	-.65	-.67	0.79
82	27	-.55	-.52	0.89
84	25	-.35	-.35	0.87
85	27	-.50	-.50	0.91
86	26	-.37	-.47	0.77
87	26	-.45	-.35	0.88
90	26	-.37	-.40	0.87
103	17	-.70	-.60	0.58
104	25	-.52	-.31	0.88
106	25	-.37	-.34	0.93
115	25	-.53	-.51	0.82
122	28	-.63	-.54	0.79
142	24	-.42	-.54	0.85
143	27	-.41	-.17	0.54
149	23	-.46	-.37	0.89
153	25	-.63	-.38	0.82
156	25	-.53	-.50	0.81
158	24	-.65	-.52	0.88
160	23	-.70	-.60	0.89
161	28	-.59	-.56	0.91
163	26	-.36	-.55	0.85
168	24	-.20	-.11	0.91
170	27	-.44	-.28	0.84

TABLE 5. **Ranking of interior white spruce families according to mean wood density, diameter (OBDBH), and height. Ranking is from highest to lowest.**

Ranking	Family No.	Density (kg/m³)	Family No.	Diameter (mm)	Family No.	Height (m)
1	104	443	3[a]	52.9	87	3.77
2	90	441	87	52.1	161	3.61
3	6[a,b]	429	160	50.5	17	3.54
4	15	424	22	50.0	6[a]	3.53
5	25	419	161	49.0	16	3.50
6	41	419	40	48.9	22	3.49
7	13	417	9	48.6	40	3.47
8	3[a]	416	17	48.4	143	3.42
9	103	415	6[a]	48.2	84	3.41
10	80	415	84	47.5	9	3.40
11	122	414	80	47.3	3[a]	3.38
12	21	414	21	47.1	26	3.38
13	149	412	16	47.0	27	3.38
14	156	410	26	46.1	21	3.37
15	84	408	103	46.0	160	3.37
16	163	408	115	45.7	85	3.31
17	39	407	122	45.5	15	3.29
18	170	407	39	45.5	80	3.27
19	153	406	1	45.5	39	3.24
20	143	405	15	45.2	1	3.24
21	27	405	143	45.1	158	3.21
22	9	404	82	44.7	25	3.17
23	26	404	86	44.2	13	3.17
24	142	404	25	44.0	115	3.16
25	40	403	27	43.9	103	3.15
26	161	402	158	43.8	86	3.14
27	115	402	142	43.7	122	3.10
28	160	400	85	43.6	142	3.08
29	36	399	13	42.6	163	2.97
30	85	397	153	41.8	170	2.97
31	158	395	156	40.9	82	2.96
32	106	394	163	40.3	36	2.89
33	17	394	170	40.2	104	2.89
34	16	394	106	40.1	106	2.85
35	1	391	36	38.4	168	2.82
36	82	391	168	38.3	153	2.80
37	168	391	104	38.0	156	2.76
38	86	390	41	37.2	41	2.75
39	87	389	149	35.5	149	2.71
40	22	384	90	33.2	90	2.60

[a] Families within the top 25% highest wood density, diameter, and height.

[b] Underlined family numbers have equal or higher than average wood density, diameter, and height.

FIGURE 1. Average annual ring density trends at breast height from pith to bark for interior white spruce in British Columbia (Jozsa and Kellogg 1986).

FIGURE 2. Density profile from pith to bark for young interior white spruce trees from family No. 107 (Gonzalez 1990).

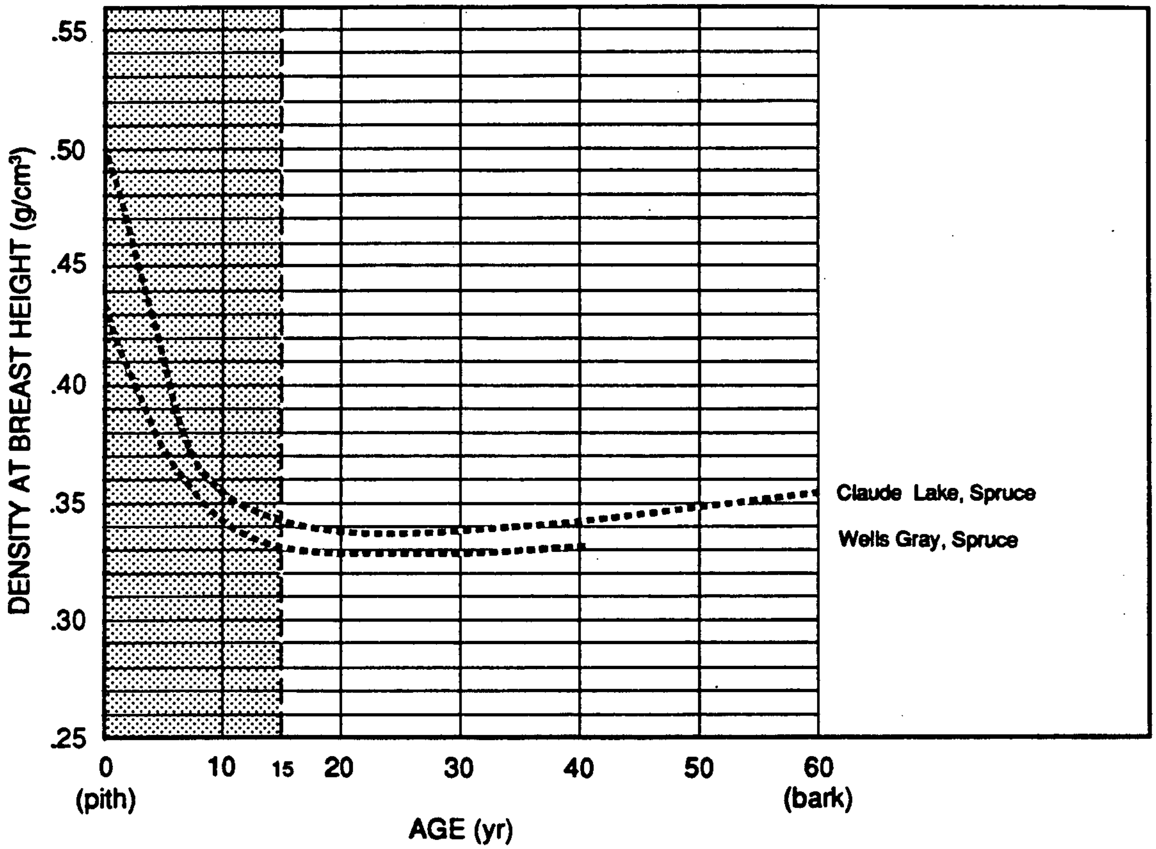

Figure 1 Average annual ring density trends at breast height from pith to bark for interior white spruce in British Columbia. (Jozsa and Kellogg 1986)

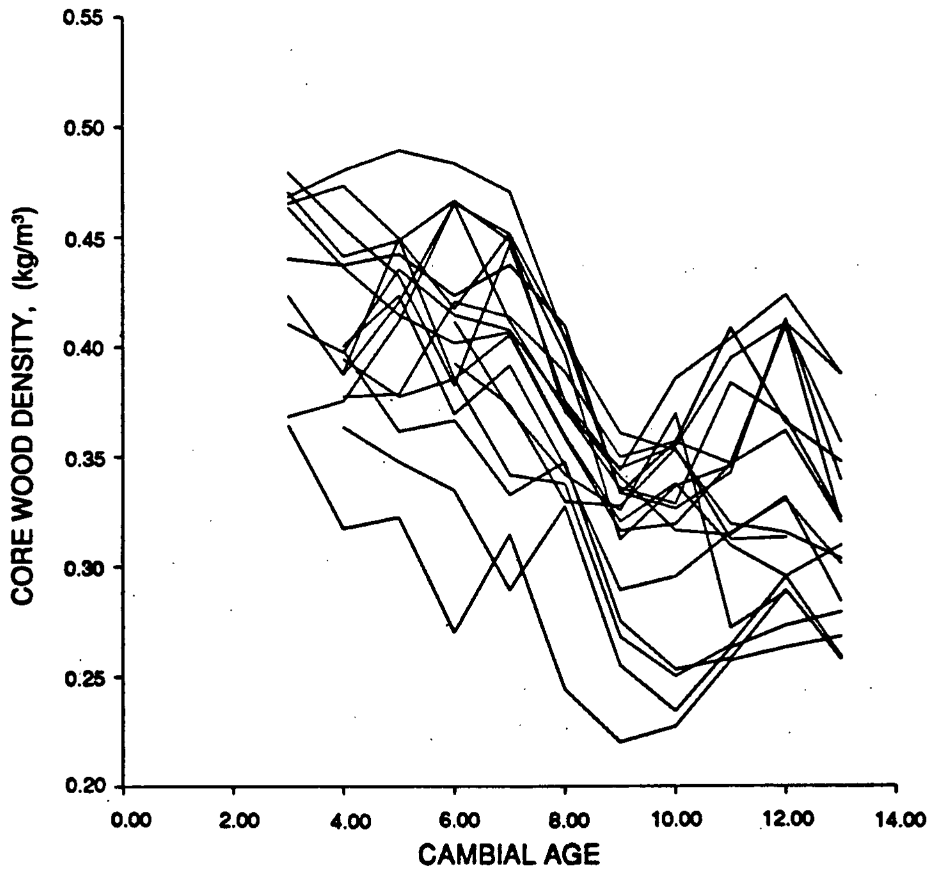

Figure 2 Density profile from pith to bark for young interior white spruce trees from family #107 (Gonzalez 1990)