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SPECIFIC GRAVITY AND RATE OF growth OF SPRUCE IN NORTHERN ONTARIO

by

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Charles G. Allen

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INTRODUCTION

Canadian spruce pulpwood is purchased by the cord. However, the yield in wood pulp per cord of pulpwood varies so much that the cord is not a satisfactory marketing unit. One factor suggested as a cause of the variation in yield is specific gravity of the wood making up the cord.

The purpose of this paper is to determine the variation of specific gravity in Canadian black and white spruce wood and if that variation is caused by differences in forest conditions. The study is primarily concerned with spruce on limits of the Detroit Sulphite Pulp & Paper Company.

PREVIOUS STUDIES ON THE SPECIFIC GRAVITY OF WOOD

The variability of specific gravity has long been recognized. Variation occurs within one species as well as between species.

Bray and Paul (3) point out that wood of the southern pines decreases in weight per unit of volume from the stump upwards in the tree. Hale and Prince (10) found this same trend in spruce and balsam in eastern Canada. On the other hand, in a study of white spruce, Hale and Fensom (9) reported that "the spruce in this study was found to have a higher specific gravity near the top of the tree than at the butt."

Baxter[1] stated that he found the density of northern white cedar to vary within the tree from butt to the tip and from the pith to the perifery.

The Committee of Pulpwood of the Canadian Pulp and Paper Association concluded, in a study of spruce stands in Quebec, that the slow growing "swamp" spruce fell in the class of wood of low density (4). This conclusion, however, is contrary to the results reported by such investigators as Prince and Hale (10), the Wood Measurement Committee (5), and Peck (6).

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[1] Baxter, D.V. 1940. Associate Professor of Silvics and Forest Pathology, School of Forestry and Conservation, University of Michigan.

Wood of the same species produced in the same stands varies greatly in density due to the presence of rotholz or compression wood. The occurrence of rotholz gives rise to wide variations in weight and tends to destroy the relationship of specific gravity to diameter (10).

Site conditions have a marked influence on wood density. ". . . . it is reasonable to expect that poor dry sites would produce wood of a different character than rich moist sites . . . ." (12). Specific gravity of wood varies with locality (5) and with the degree of stocking.

Chidester, Bray, and Curran (7) reported a positive correlation between unit weight and diameter in jack pine; i.e. in general, the larger the diameter the lighter the wood. By irrigation Paul (14) obtained fast growing southern pine trees having a high summer-wood content and hence a high specific gravity. According to Kynoch[1], fast growing coastal Douglas fir frequently contains a high percentage of summer-wood and consequently, has a high specific gravity.

The findings recorded in all of the literature reviewed differ so that any results obtained must be qualified to meet only the particular stands in question. Data obtained in Quebec are not necessarily applicable to stands in Ontario or Manitoba. Specific gravity figures for "swamp"

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[1] Kynoch, W. Professor of Wood Technology, School of Forestry and Conservation, University of Michigan.

spruce in the Abitibi District, Ontario, are not likely to apply to the "highland" spruce of that same district.

METHODS USED IN DETERMINING SPECIFIC GRAVITY IN CANADIAN SPRUCE

The investigation of the variation in specific gravity of black and white spruce in Canada was conducted in three steps. First an early study was made on spruce wood from Canada to obtain information which would aid in the field sampling of spruce stands. Secondly, sample trees of black and white spruce were collected in the Cochrane District, Ontario. Thirdly, specific gravity determinations of the sample trees collected were made.

Spruce Test Samples Used In the Early Study

Sample disks for this study were cut from the ends of peeled spruce sticks and sent to the laboratory by the Driftwood Lands and Timber Limited[1], Burt, Ontario. The disks represented wood grown on three different forest types; namely, swamp spruce, highland spruce, and the transition zone, termed "sub-type".[2]

In the laboratory these disks were separated by the forest type which they represented, by one inch diameter

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[1] A subsidiary of the Detroit Sulphite and Paper Co., Detroit, Michigan.

[2] These "types" were recognized in this study because they are used by the company. They do not coincide with the spruce types designated by the Lake States Forest Experiment Station which bases type classification on plant indicators.

classes, and by rate of growth (0-25 rings per inch, 26-50 rings per inch, and 50 rings and up). The average number of rings per inch of radius and the average growth rate for the past 50 years was determined for each sample.

The disks were then dried in temperature controlled ovens to obtain the oven-dry weight of the wood. The dry samples were dipped in paraffin and their oven-dry volume determined by water displacement.

The ratio of unit weight to unit volume (density) was thus obtained on the bases of weight oven-dry and volume oven-dry.

Excepting the larger samples, specific gravity determinations were made on the whole disk. Disks of the bigger diameters required more oven space than was available. Consequently, the density of these samples was based on pie-shapped segments cut from the portion of the disk including the average radius[1].

The specific gravity data were then plotted by diameter class and forest type to find the relationship existing between density and diameter, density and rate of growth, and density and forest type.

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[1]When the average raduis fell in portions of the disk containing a high percentage of rotholz, the segments were cut from a section of the disk having little or no compression wood.

Field Sampling

During the second week in April, I made a field study on approximately 1000 acres of a spruce-balsam forest owned by the Detroit Sulphite Pulp and Paper Co. in the N.W. $\frac{1}{4}$ of the N.E. $\frac{1}{4}$ of Lennox Township, Cochrane District, Ontario.[1]

A $2\frac{1}{2}$ % strip-line cruise was run on the area and the timber tallied by forest type (swamp, sub-type or highland type), one inch d.b.h. classes and genera. Since the hardwoods are inferior species for pulping (white birch, aspen and cottonwood), these trees were not tallied.

The cruise data were compiled at nights to construct a stand and stock table showing the diameter range, and the volume percentage by diameter classes.

Ten sample spruce trees representing each of the predpminant d.b.h. classes of the sub-type and five for each d.b.h. class of the highland spruce were felled. Each sample tree was tallied by type, d.b.h. class, total height and merchantable height. The trees were cut 12"-18" above the ground and sectioned into eight-foot sticks to a merchantable top of four inches. A two-inch disk was taken from the large end of each stick and from the end section of the remaining top portion of the bole (Figure 1).

The disks were then bagged and shipped to the laboratory in Ann Arbor.

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[1]By permission of the Detroit Sulphite Pulp and Paper Company, Detroit, Michigan.

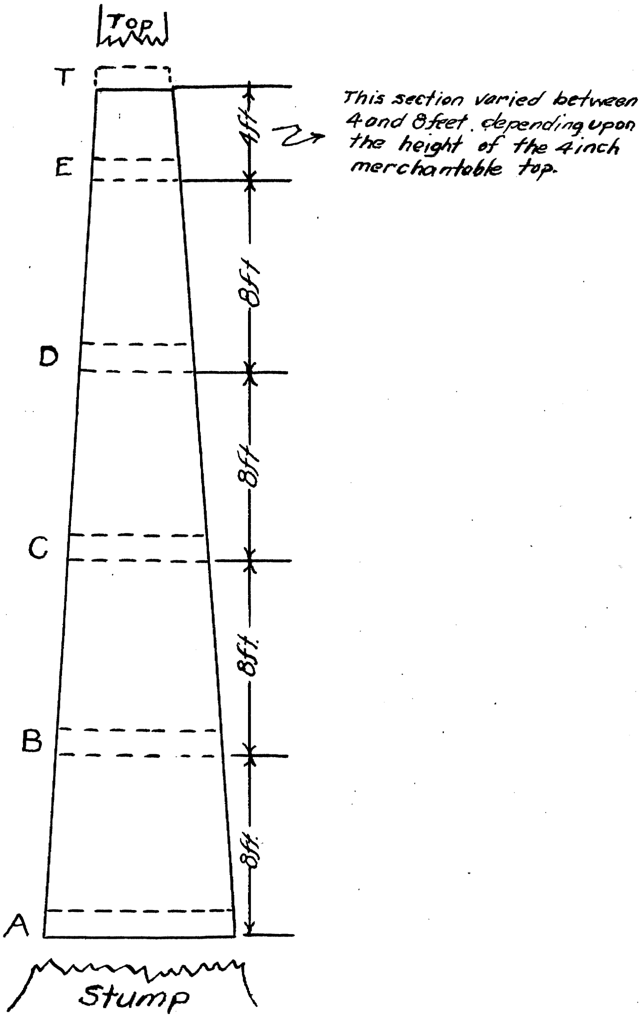

Figure 1. The position of the disks selected from each sample tree.

Specific Gravity Determinations

The samples obtained during the field study were segregated by types and stacked by tree numbers. After the removal of the bark from the disks, the same procedure as used in the early study was employed to determine the relationship of the average density of the sample trees to diameter, total growth rate, growth rate for the past 50 years, and to the position from which the disks were taken in the sample trees.

RESULTS

Specific Gravity of the Early Test Specimens

Efforts to correlate density with total age as obtained along the average radius failed. However, when the rate of growth was broken into three classes, fast (0-25 rings per inch), medium (26-50 rings per inch), and slow growth (50 rings and up), smooth curves of specific gravity data and growth rate by diameter classes were plotable (Figure 2).

The relationship of specific gravity to diameter was found to be indirect (Figure 3). In general, the larger the disk the lower the specific gravity.

Cruise Data

On the bases of the 2½% cruise the stand consists of 132.31 spruce trees per acre carrying a volume of 11.75 cords of rough spruce wood to the acre (Tables I and II). Peeling will reduce this volume 20.68% to give a volume per acre of 9.32 cords.

The swamp type spruce stands carry an average of .76 cords of rough wood to the acre. Balsam occurred most frequently in the highland type and will yield approximately 3.63 cords per acre. This brings the total volume up to 16.14 cords of rough wood per acre.

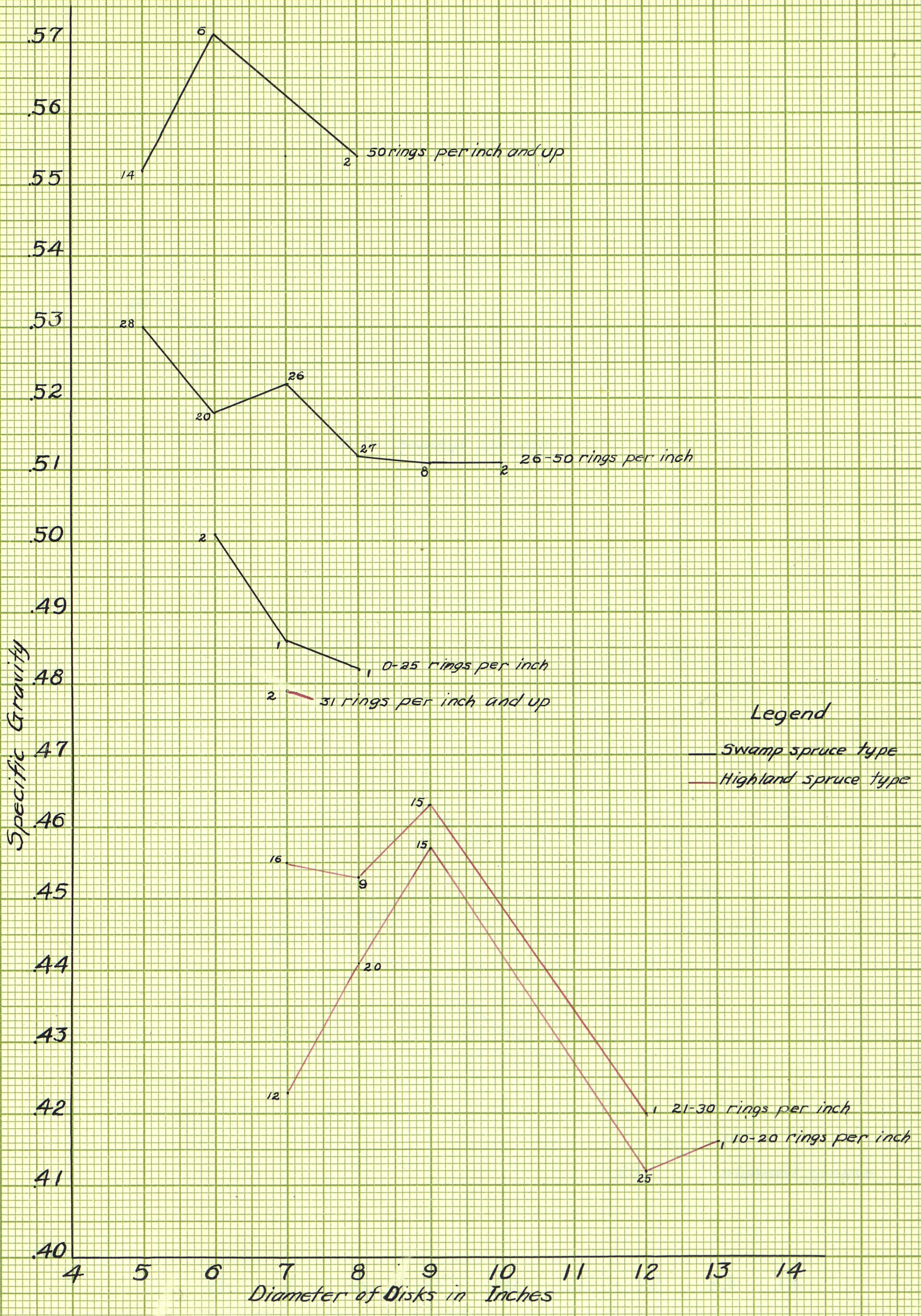

Figure 2 The correlation of specific gravity of individual disks with rate of growth by diameter classes.

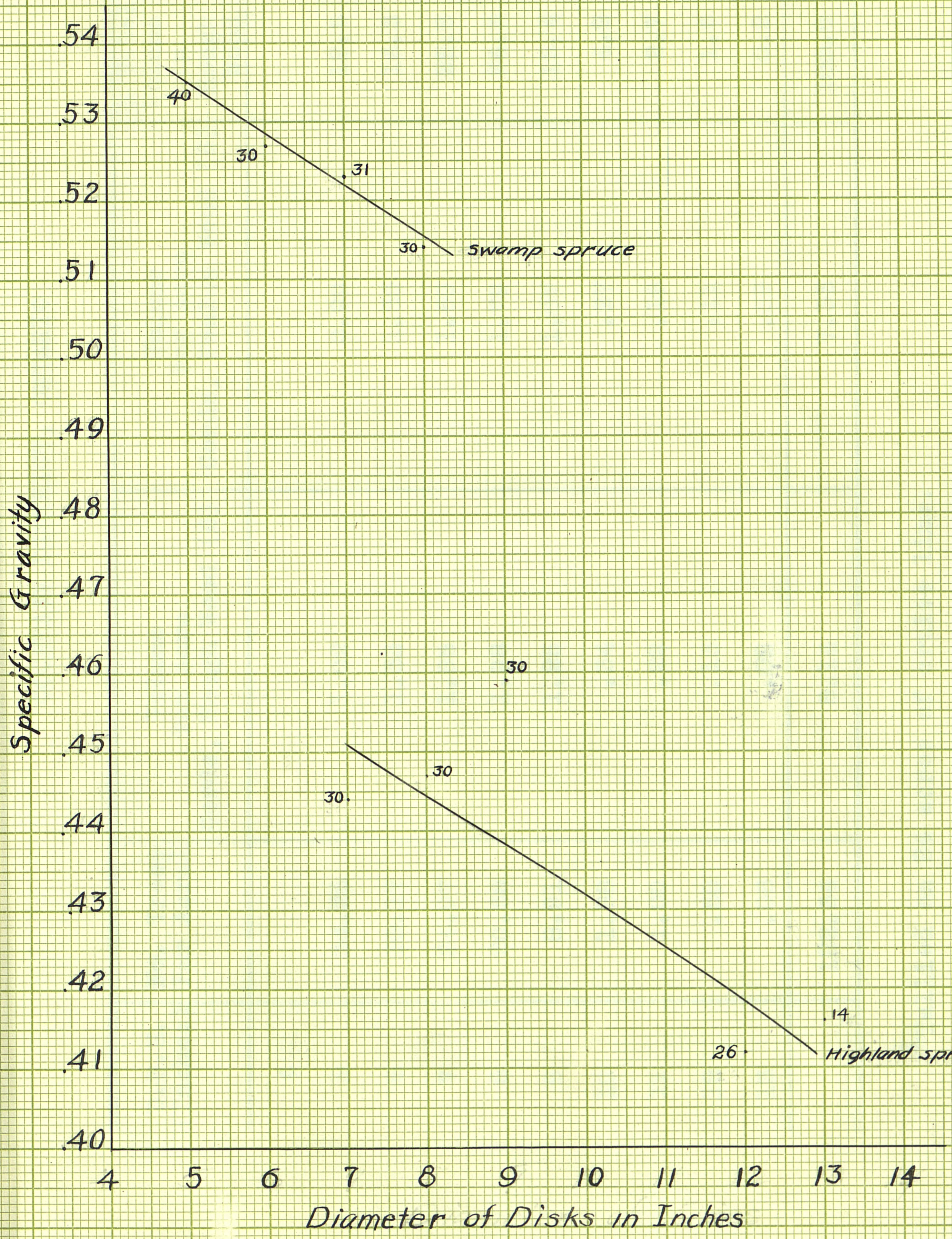

Figure 3. The relationship of specific gravity of individual disks to diameter

TABLE 1

STAND AND STOCK TABLE FOR SPRUCE SUB-TYPE

COCHRANE DISTRICT, ONTARIO

D.B.H. (Inches)	No. Trees Per Acre[1]	Volume Per Acre Cords, Rough Wood (6)	Volume Per Acre Cords, Peeled Wood (6)	% Total Volume in Rough Wood	% Total Volume in Peeled Wood
4					
5	34.25	1.02	0.99	12.5	13.5
6	30.17	1.33	1.30	16.3	17.8
7	24.97	1.85	1.60	22.8	21.8
8	20.58	1.98	1.79	24.3	24.3
9	8.91	1.25	1.07	15.4	14.6
10	1.88	.34	.27	4.2	3.7
11	1.00	.22	.18	2.7	2.5
12	.50	.13	.11	1.6	1.5
13	.08	.02	.02	0.2	0.3
	122.34	8.14	7.33	100.0	100.0

[1]Tallied on 24 acres of cruise line.

TABLE II

STAND AND STOCK TABLE FOR HIGHLAND SPRUCE TYPE

COCHRANE DISTRICT, ONTARIO

D.B.H. (Inches)	No. Trees Per Acre[1]	Volume--Cords Per Acre Rough Wood (6)	Volume--Cords Per Acre Peeled Wood (6)	% Total Volume in Rough Wood	% Total Volume in Peeled Wood
5	2.08	0.06	0.060	1.66	2.01
6	2.17	0.10	0.098	2.77	3.28
7	2.67	0.20	0.171	5.54	5.73
8	3.04	0.32	0.265	8.87	8.98
9	2.54	0.36	0.304	9.98	10.19
10	1.42	0.26	0.207	7.20	6.94
11	1.08	0.24	0.196	6.65	6.56
12	1.21	0.34	0.266	9.42	8.90
13	0.79	0.26	0.212	7.20	7.10
14	1.08	0.42	0.335	11.64	11.22
15	0.58	0.26	0.217	7.20	7.26
16	0.58	0.30	0.249	8.30	8.34
17	0.08	0.05	0.037	1.38	1.24
18	0.33	0.21	0.175	5.82	5.86
19	0.12	0.08	0.069	2.22	1.97
20	0.12	0.09	0.075	2.49	2.52
21					
22	0.04	0.03	0.027	0.83	0.95
23					
24	0.04	0.03	0.027	0.83	0.95
	19.97	3.61	2.990	100.00	100.00

[1]Tallied on 24 acres of cruise line.

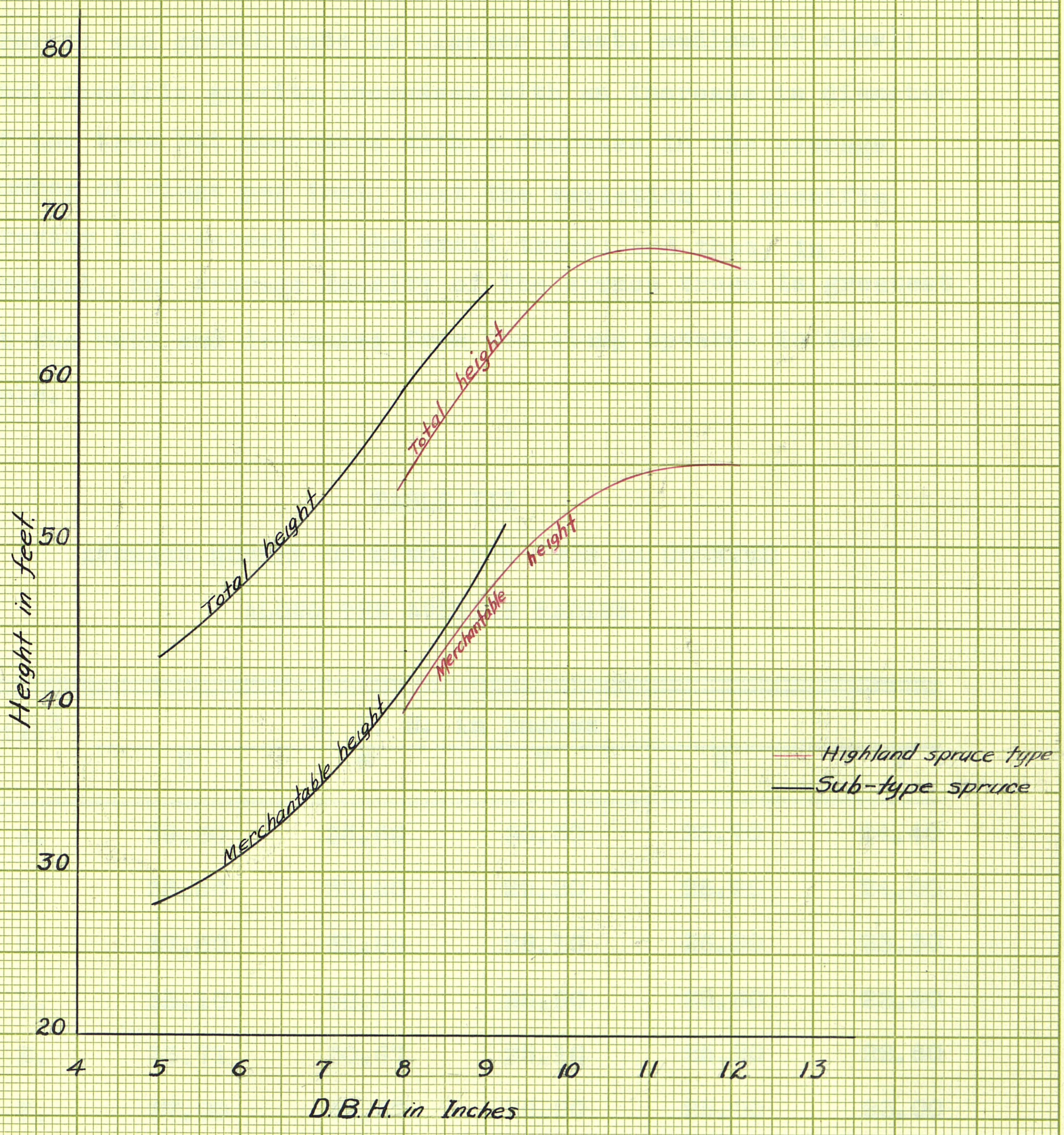

Figure 4. Height curves based on measurements taken from 75 sample trees; 50 of sub-type and 25 of highland type.

Specific Gravity of the Field Samples

The findings of this portion of the study are: that there is no single relationship existing between specific gravity and growth rate by classes (fast, medium or slow); that specific gravity increases with an increase in diameter of the tree but decreases with a decrease in the average number of rings per inch; that the variation in specific gravity is greatest in the small trees; and that, in general, the average density of the spruce trees is greatest at the butt and decreases from the stump upwards in the bole.

TABLE III

AVERAGE NUMBER OF RINGS PER INCH AS COUNTED ALONG THE AVERAGE RADIUS

Disk[1]	D. B. H. in Inches				
	5	6	7	8	9
A.	39.30	35.60	30.30	26.70	24.40
B.	38.50	33.20	29.20	26.90	24.00
C.	37.60	31.60	28.10	26.20	23.30
D.	35.10	30.70	25.80	25.60	23.50
E.	33.71	30.67	25.10	25.20	22.60
F.	37.00	31.67	26.20	25.00	23.00
G.				26.86	23.14
H.					23.75
I.					23.00

[1] Disk A was taken at stump height (12-18"), B at 8 feet above the stump, C, 16 feet, D, 24 feet, etc.

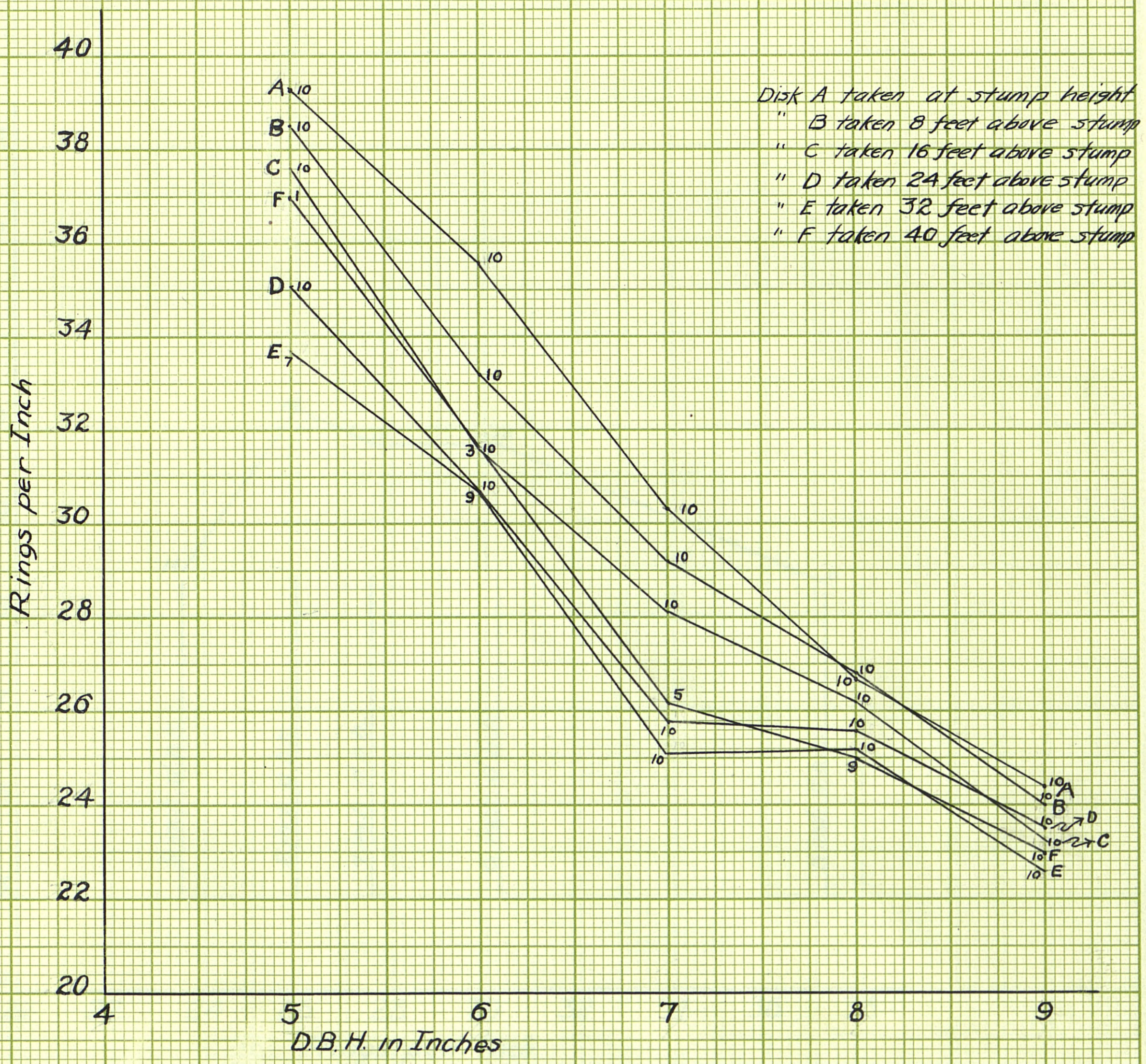

Figure 5 Rate of growth of sub-type spruce wood according to position in the stem of the tree.

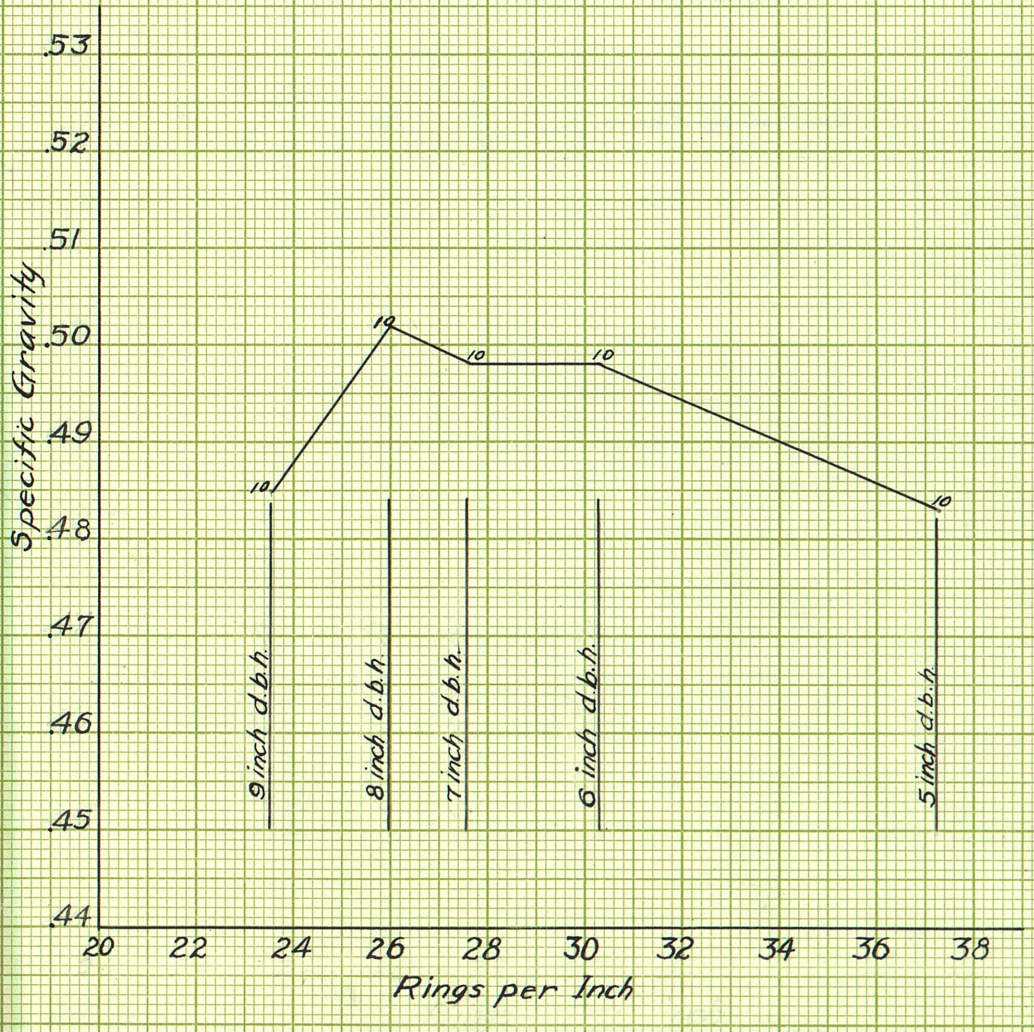

Figure 6. The variation of specific gravity with growth rate by diameter classes.

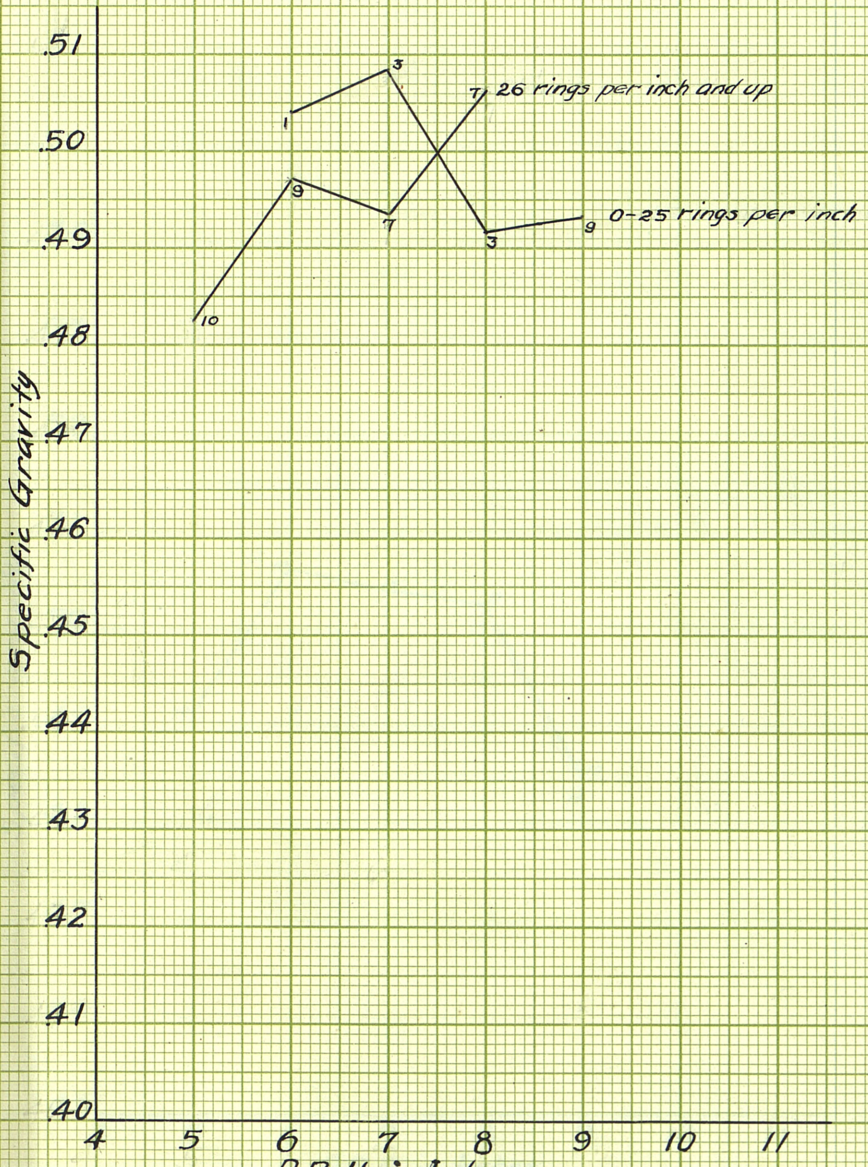

Figure 7. The relationship of specific gravity of the sample trees to growth rate by diameter classes.

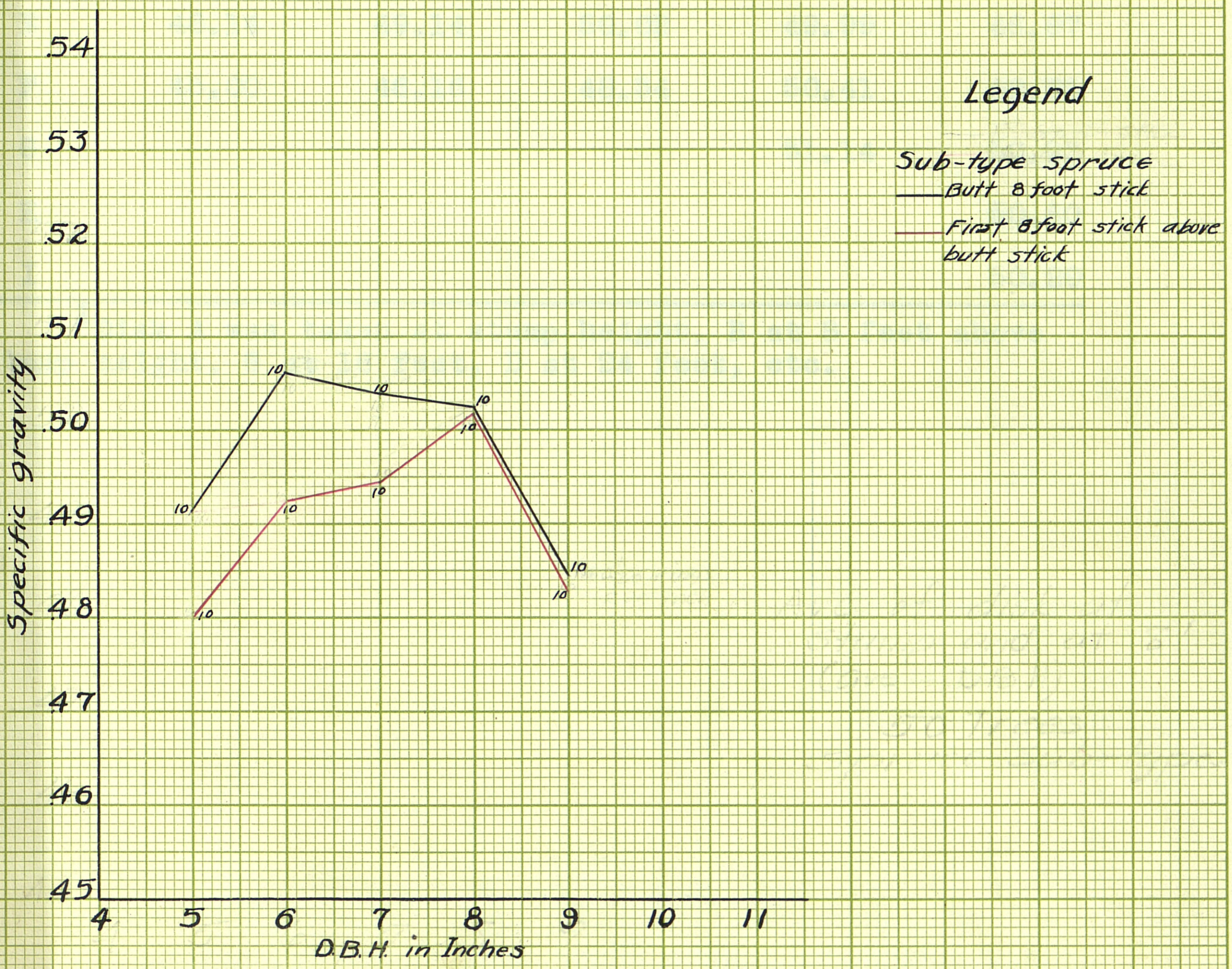

Figure 8. Variation in specific gravity between the first and second stick in the tree.

TABLE IV

AVERAGE SPECIFIC GRAVITY OF THE DISKS BY D.B.H.

CLASS AND POSITION IN THE TREE
(In Percent)

Disk[1]	D.G.H. in Inches				
	5	6	7	8	9
A	49.33	51.30	50.96	50.00	49.31
B	48.89	49.94	49.83	50.27	47.57
C	48.05	49.77	49.31	50.31	47.99
D	47.95	48.74	49.34	49.84	48.57
E	48.14	49.14	50.02	49.99	46.87
F	45.00	46.16	48.54	50.41	48.75
G				51.14	50.93
H					50.60
I					50.20

[1]Disk A was taken at stump height, B at 8 feet above stump height, C at 16 feet, D at 24 feet, etc.

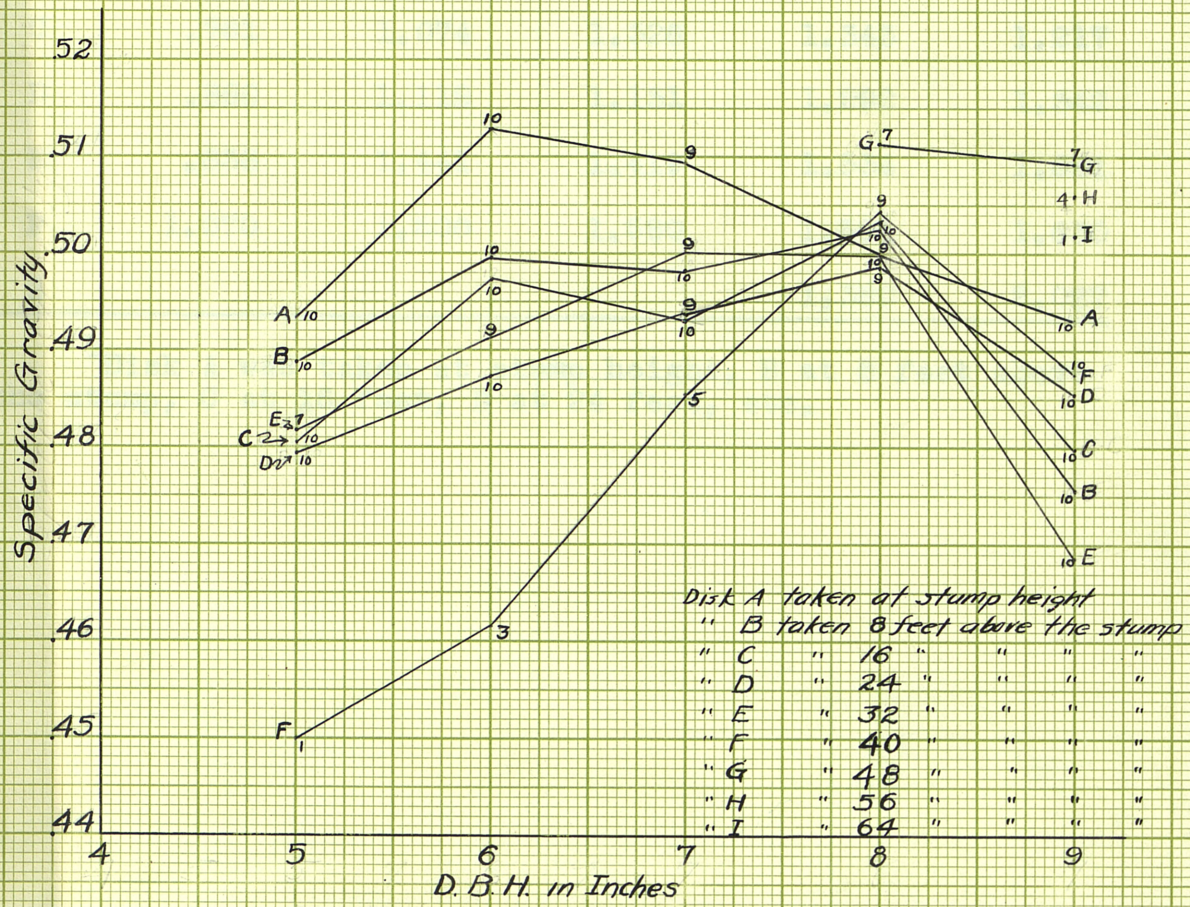

Figure 9. Specific gravity of sub-type spruce wood according to position in the stem of the tree.

TABLE V

AVERAGE RADIAL GROWTH IN INCHES DURING THE LAST 50 YEARS ACCORDING TO D.B.H. AND POSITION OF DISK IN THE TREE

Disk[1]	D.B.H. in Inches				
	5	6	7	8	9
	Inches	Inches	Inches	Inches	Inches
A	.713	1.126	1.334	1.544	1.355
B	.675	.937	1.193	1.355	1.162
C	.761	1.074	1.326	1.343	1.217
D	.880	1.112	1.131	1.292	1.342
E	.838	1.441	1.419	1.534	1.621
F	1.070	1.500	1.580	1.591	1.630
G				1.380	2.027

[1]Disk A was taken at stump height, B at 8 feet above the stump, C at 16 feet, D at 24 feet, etc.

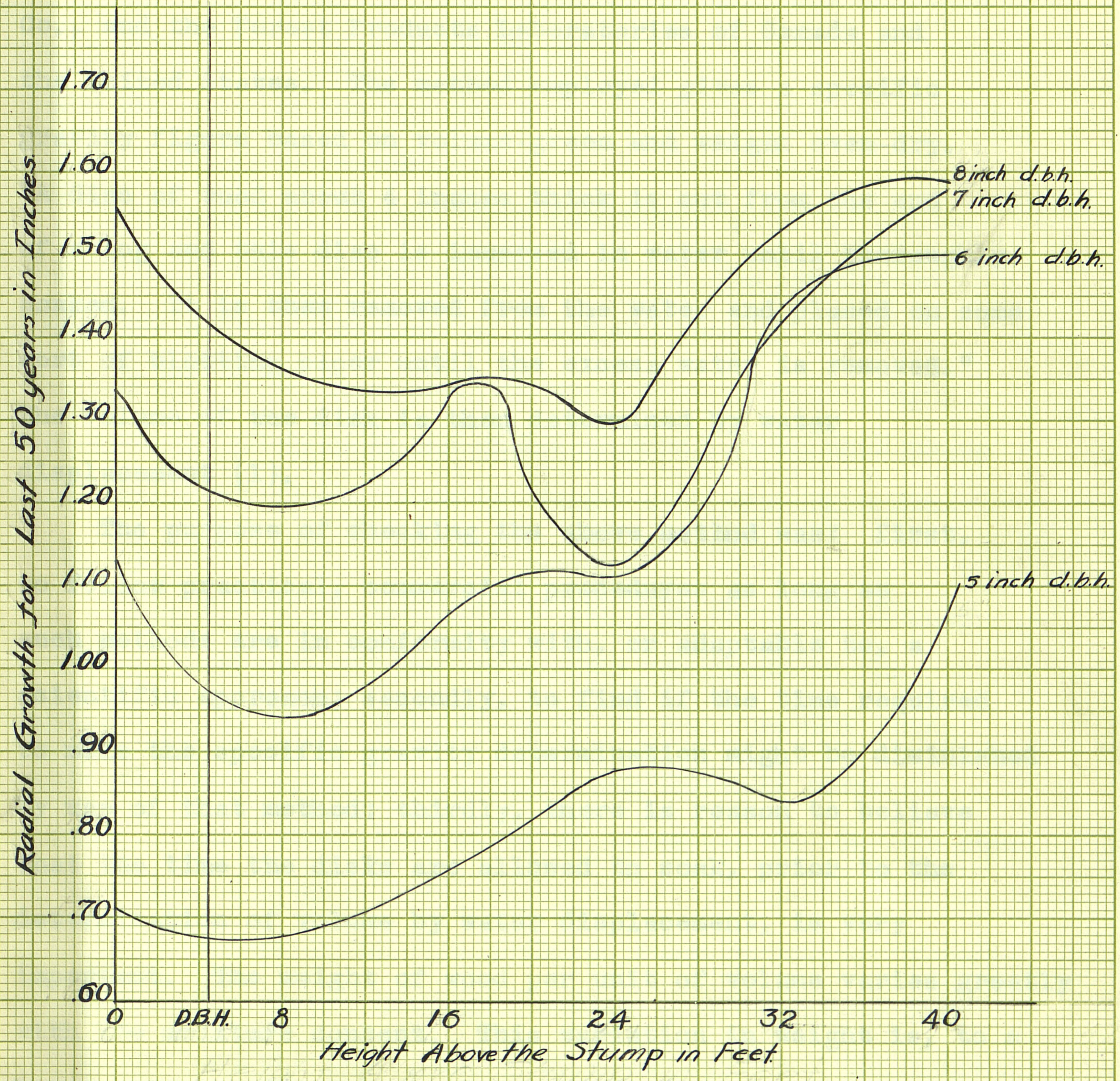

Figure 10 Radial growth for the last 50 years according to position in the stem of the tree.

DISCUSSION

Early Study

Considerable work was done in an attempt to check the method of determining the specific gravity used by the Detroit Sulphite Pulp & Paper Co., the Hammermill Paper Co., and the Forest Products Laboratories of Canada and the United States. The method employed gives a specific gravity figure based on volume-green and weight oven-dry. "A disc of wood about 4 inches thick is cut from the end of a log and this disc is immersed in water until thoroughly soaked. It is then removed from the water and placed on some sort of blotting paper until the excess water is removed." The volume of the disk is then determined by water displacement (1).

The purpose of checking the above method was: first, to follow practical, commercial procedures as long as such methods are in conformity with, or adaptable to, a scientific approach; secondly, to find if the time required to make the specific gravity determination might be diminished by use of that method; thirdly, there is reason to believe that the time the disks are allowed to soak, prior to the determination of volume by water displacement, is very important. The weight of wood per unit of volume varies greatly with the moisture content. This variation in weight is, to a large extent, offset by an increase or decrease in volume.

At moisture content percentages above the fiber saturation point of the wood, the weight per unit of volume is decidedly affected by changes in moisture conditions " because there is no offsetting change in volume" (15). To arrive at an accurate specific gravity figure by the above method, it is felt that the fiber saturation point of the species in question should be determined and that the disks should be soaked for a period which will bring their moisture content to that point. This would standardize the soaking period and give a truer volume figure per unit of weight.

Determination of the fiber saturation point of spruce wood and the time period required to soak the samples to bring the moisture content of the disks to that point, necessitates more time than was available. Consequently, the specific gravity of the disks reported on in this paper was determined on the bases of weight oven dry and volume oven dry.

Since the disks used were taken from the ends of pulp sticks already cut, it was impossible to ascertain the position which these disks occupied in the standing tree. It is evident, then, that specific gravity data given in Figures 2 and 3 refer to individual disks and not to the stem of the tree as a unit.

Disks cut from the slow growing swamp spruce exhibited a considerably higher average specific gravity figure than did those from the fast growing highland spruce. The difference is not necessarily due to growth conditions alone. Disks of the swamp spruce type were practically all black spruce, whereas the majority of the highland type disks were white spruce. In general, the density of black spruce runs from one to five percent higher than that of white spruce (11).

Field Cruise

The forest cruised is a 100 year old white and black spruce-balsam forest. On the bases of a yield table for black spruce published by the Lake States Forest Experiment Station (13), the stand is, on the average, about 41% stocked. Some portions of the limit have a stocking of less than the average and some considerably higher than 41%.

The undulating terrain made type mapping impractical. On cruise lines the timber types were interspersed to such as extent that segregation of the types was based on bark characteristics rather than topography. However, the true "swamp" type was easily recognizable by terrain features as well as bark chacteristics. This type occurred infrequently and supported such a meager volume that no yield may be expected from it in this season's cut. Consequently, no sample trees of this type were taken.

Sample trees were selected by the striation method of sampling. Use of this method eliminated the variation in specific gravity of the spruce wood due to diameter, forest genera and type.

The height curves (Figure 4) were drawn from the data obtained from the sample trees felled. These curves checked closely with height curves made by Haavaldsrud[1] on 300 white and black spruce trees in similar spruce-balsam stands on adjacent limits.

Specific Gravity of the Field Samples

In discussing the results of these tests, it is emphasized that to present conclusive data would require a study much wider in scope than has been possible here. This report includes only data obtained from samples of the sub-type b-lack and white spruce forest.

The fact that the average specific gravity of the trees is greater in the larger, faster growing stems is evidence that site conditions are such that the production of summerwood has kept pace with the rate of growth. In the smaller trees the marked variation in rate of growth taking place at different heights (Figure 5) indicates that, at various intervals, these trees have been surpressed by the more vigorous individuals during which periods the production of summerwood was curtailed. Figure 8 illustrates this better than Figure 5. The difference in density of the first tow sticks above the stump is over one percent in the five, six, and seven inch d.b.h. classes, whereas it is less than .2% in the two larger diameter classes. The average number of rings per inch for these same two sticks differs from 2.5 to 3.25 in the five, six and seven inch d.b.h.

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[1] Haavaldsrud, Olav. Field Forester. Detroit Sulphite Pulp and Paper Co., Detroit, Michigan.

classes. In the larger diameters the difference in the average annual ring count per inch is less than 1.

For the past 50 years growth rate has been materially reduced in all diameters. This reduction is more marked in the smaller trees. At d.b.h., the five inch trees have produced less than 30% of their radial growth in the latter half of their lives. The eight inch class has put on over 35% of its radial growth in the same period (Table V).

Compression wood is prevalent throughout the sample trees. The presence of rotholz has undoubtedly had a marked effect on the present findings and may be responsible for the direct relationship between density and growth rate.

CONCLUSIONS

This investigation points to the conclusion that the yield per cord of pulpwood is greater in the cords containing sticks of the larger diameter classes than in those made up of smaller sticks. This conclusion is bolstered by the fact that the larger the bolts the higher the solid cubic foot content of the stacked cord.

However, it is emphasized that, since the number of sample trees studied was a minimum, the conclusion can only be a tentative trend and should be tested by extended studies. A minimum of 20 sample trees per diameter class for each of the forest types is suggested.

SUMMARY

1. Specific gravity of Canadian black andwhite spruce varies indirectly with diameter of the individual disks but directly with the diameter when applied to the stem of the tree as a unit[1].

2. The effect of the growth rate (by classes) upon specific gravity is much greater in individual disks than in the tree as a whole[1].

3. The average specific gravity of the sub-type black and white spruce trees is greatest at the butt of the trees and decreases with increasing height lèvels in the stems.

4. Spruce wood of this type varies from .482 in specific gravity in the five inch d.b.h. class to .502 in the nine inch d.b.h. class.

5. Site conditions may be such that the fast growing trees produce a high percentage of summerwood and thus yield wood of high density.

6. Further study is needed to substantiate the results of this investigation.

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[1] Average specific gravity and average growth rate data for the tree as a unit were obtained by averaging the data of the disks taken from a sample tree.

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