O.D.C. 56:174 Picea glauca
(713):566

CANADA
DEPARTMENT OF FORESTRY
AND RURAL DEVELOPMENT

# WHITE SPRUCE PLANTATION GROWTH AND YIELD AT THE PETAWAWA FOREST EXPERIMENT STATION

by
W. M. Stiell and A. B. Berry

*Extrait en français*

THIS FILE COPY MUST BE RETURNED

TO: INFORMATION SECTION,
NORTHERN FOREST RESEARCH CENTRE,
5320-122 STREET,
EDMONTON, ALBERTA.
T6H 3S5

FORESTRY BRANCH

DEPARTMENTAL PUBLICATION No. 1200
1967

Published under the authority of the
Minister of Forestry and Rural Development,
Ottawa, 1967

ROGER DUHAMEL, F.R.S.C.
QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1967

Catalogue No. Fo 47-1200

## ABSTRACT

Yield tables for unmanaged, high-survival, white spruce plantations are presented by 5-year-age classes up to 40 years from planting, for 5 planted spacings and 4 site index classes. Each table includes data for numbers of trees per acre, mean d.b.h., basal area, total volume, and merchantable cubic volume.

## EXTRAIT

Les tables de rendement produites dans cet article sont basées sur les données obtenues dans certaines plantations d'Épinette blanche (*Picea glauca* (Moench) Voss), à la Station d'expériences forestières de Petawawa, Ontario. Elles concernent, plus particulièrement, les plantations non aménagées et vigoureuses, et tiennent compte de 5 espacements différents, de 4 classes de fertilité, et de classes d'âge de 5 ans en 5 ans jusqu'à 40 ans. En outre, elles renseignent sur le nombre d'arbres à l'acre, le d.h.p. moyen, la surface terrière, le volume total et le volume marchand en pieds cubes.

## CONTENTS


| | Page |
|---|---|
| INTRODUCTION | 1 |
| THE PLANTATIONS | 2 |
| METHODS | 2 |
| Sample Plots | 2 |
| Site Index Curves | 2 |
| Mortality Rates | 3 |
| Stand Diameters | 6 |
| Stand Volume Tables | 7 |
| Yield Tables | 9 |
| REFERENCES | 15 |

# WHITE SPRUCE PLANTATION GROWTH AND YIELD AT THE PETAWAWA FOREST EXPERIMENT STATION

by
W.M. Stiell and A.B. Berry[1]

## INTRODUCTION

Large-scale planting of white spruce (*Picea glauca* (Moench) Voss) in Ontario is a recent development. There are relatively few long-established plantations of this species, and these are the only sources of growth data for predicting what could be expected from today's planting. The province's largest aggregate of older white spruce plantations, which is at Petawawa, exceeds no more than about half rotation age but can provide useful interim information.

Two harvesting approaches are possible for plantations. Periodic yields can be obtained by regular thinnings that conform to yield tables constructed for the purpose. Alternatively, it may be considered that clear-cutting at an appropriate age, without any intermediate treatment, is most economical. Research into both approaches is being conducted in spruce plantations at the Petawawa Forest Experiment Station. Results of thinning experiments are reported periodically (Berry, 1963; Stiell, 1965); in addition, sufficient data from untreated plantations have been accumulated to indicate relative growth at various stocking levels, which is the subject of this paper.

The following, then, deals with high-survival plantations which have developed without gross disturbance and in which any mortality that has occurred was due almost entirely to mutual competition.

[1]Research Scientist and Research Officer, respectively, Department of Forestry and Rural Development of Canada, Petawawa Forest Experiment Station, Chalk River, Ontario.

## THE PLANTATIONS

The 34 plantations of white spruce used as a basis for this study total about 80 acres. The first was established in 1922. Most planting sites were old fields, and soils include waterlaid sands, lacustrine silt loams, and sandy and loamy tills. Trees were planted in regular rows at average spacings of from 4 x 4 to 7 x 7 feet. Survival up to 30 years after planting was generally in excess of 75 per cent. Early sampling by measuring a proportion of rows in each plantation was replaced by a series of permanent sample plots, established in uniform conditions of best survival. A full description of the plantations, including their establishment, sites, and early development, is given by Stiell (1955).

## METHODS

### Sample Plots

Data for this study were provided by 45 plots, each measured from one to three times, representing stand ages of from 12 to 40 years from the planting date. On each plot all trees were tagged; after each measurement, tables of numbers of trees, basal area, and total and merchantable[2] cubic volume according to Form-class Volume Tables (Anon. 1948), were compiled. Measurements taken in about half the plots showed the range of average form class to be between 63 and 67; in the remaining plots it was assumed to be 65. Mean d.b.h., height of the tree of mean d.b.h. (from the height/diameter curve), and dominant height (average height of the tallest 10 per cent) were also calculated.

### Site Index Curves

All dominant height values were plotted over age on one graph. Joining the points for individual plots at

[2]Merchantable volume includes the bole to a 4-inch top d.i.b.

successive measurement dates produced a fan-shaped series of lines that were virtually straight beyond age 15. A line of median slope was drawn through the centre of the fan, and, with this as a guide, a family of site index curves, encompassing the range of observed data, was drawn to represent 10-foot height classes at age 40 (Figure 1). The curves have not been extrapolated beyond this age; while it seems certain that a falling-off in growth rate would ensue shortly, there is no indication as to when this might occur.

No consistent pattern of height growth could be related to physiographic site whether considered by parent material or by moisture regime (Hills and Pierpoint, 1960). Although average site class increased very slightly with moisture regime, plots over the whole range of moistures encountered (1 to 5) were found in each site class. Considerable variation in early growth rate was observed - i.e., time to reach breast height ranged from 6 to 12 years. The causes of this were not clear, but even when growth rates above breast height only are considered, there is still no correlation with moisture regime. The unsatisfactory conclusion is reached that height growth in this area cannot be predicted with much assurance before a stand age of about 15 years.

## Mortality Rates

Mortality resulting from mutual competition is taken to be a function of increasing stature of individual trees. Relating mortality to stand height, therefore, not only is reasonable but has the advantage of incorporating the effects of both age and site.

Numbers of trees per acre were plotted over dominant height for each sample plot and measurement date, and the points for individual plots were joined. The resulting lines were somewhat erratic, but they clearly indicated trends of decreasing tree numbers with increasing height. Numbers diminished more rapidly for high than for low initial stockings.

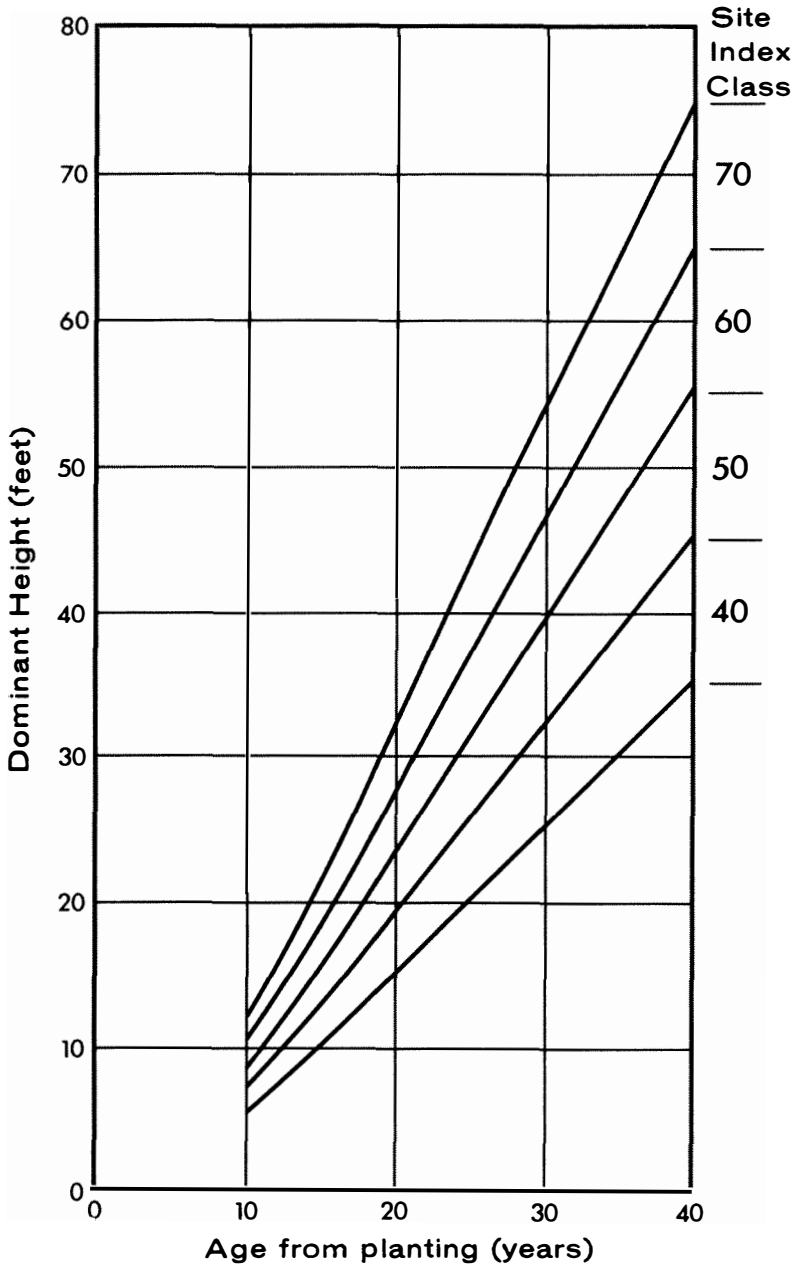


*Figure 1. Site index curves at base age 40 years for planted white spruce.*

Mortality, apart from that associated with establishment factors, did not become evident at heights of less than 20 feet except at the closest planted spacing (4 x 4 feet).

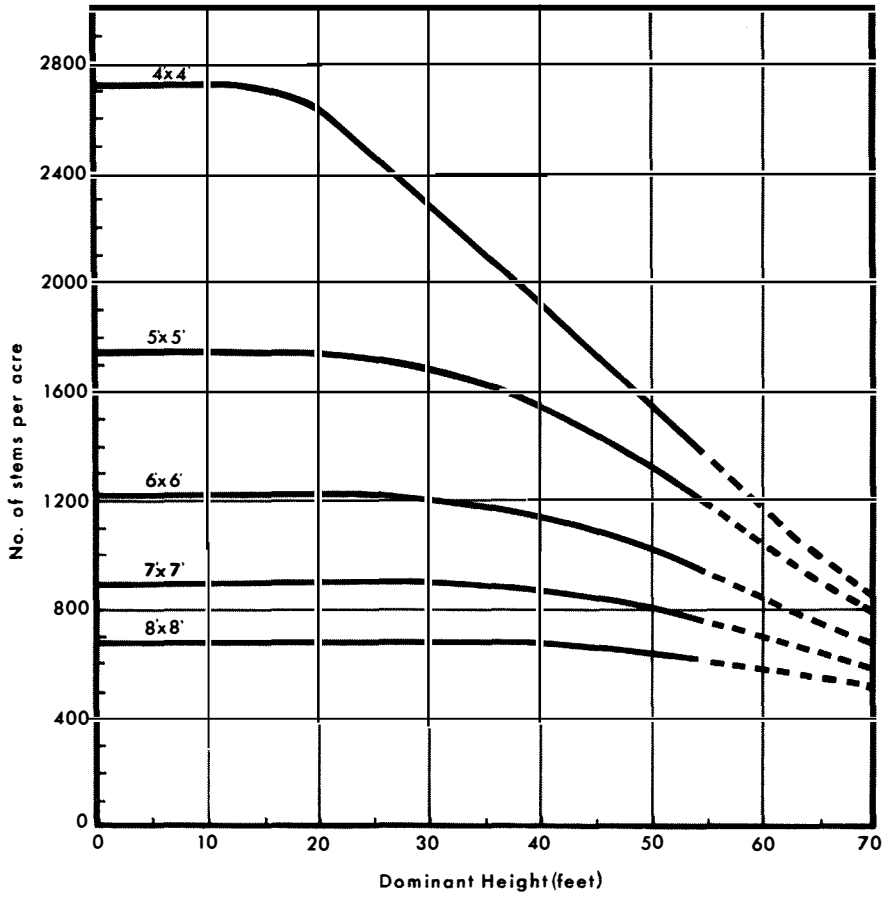


*Figure 2. Relationship of numbers of trees to dominant height, by initial spacing, for planted white spruce.*

Average numbers of trees for each 200-tree per acre stocking class were next plotted over heights of 20, 30 and 40 feet, establishing relative rates of mortality. These data, which were still irregular, were harmonized by free-hand methods, account being taken of the slopes of the individual curves and the upper and lower stocking values observed for each height class. Final curves were interpolated to represent even 1-foot-spacing classes (Figure 2).

There is little information available to suggest the probable shape of these curves, but supporting evidence is found in Beekhuis (1966). Citing his own work and that of Ferguson (1950) with pine species, he indicates that the onset

of mortality occurs earlier at high stocking densities, but at a constant "relative spacing" - i.e., ratio of spacing to height - for all densities. For white spruce, mortality, as shown by the curves in Figure 2, commences at a relative spacing of between 23 and 26 per cent at all stocking levels. In addition, Beekhuis reports that mortality prevents relative spacing from falling below about 11 per cent. The curve for the highest spruce stocking does not fall to this level and, even if produced at its present slope, would not quite intersect the 11 per cent line.

It is concluded that the mortality curves reasonably represent changes in stocking associated with increasing stand height. It should be clear that the maximum values of these curves represent numbers of established trees - i.e., numbers surviving immediate post-planting mortality.

Stand Diameters

Mean diameter (diameter of the tree of mean basal area) was found to be closely related to average spacing and dominant height (Figure 3), and, when D = mean d.b.h. in inches and SDH = average spacing in feet x dominant height in feet, can be estimated from the equation:

$$D = .99889 + .01708SDH - .000008132(SDH)^2 \qquad (R^2 = .917)$$

This quadratic function has a constraint on the X-axis to ensure that the curve culminates at SDH = 1050. This value was selected to include the maximum height (100 feet) to which white spruce would likely be grown and the equivalent numbers of trees as obtained by extrapolation of Figure 2.

A summary of diameter distributions within stands at various stocking levels is shown in Table 1. These data, which have not been harmonized, indicate the following:

(a) The range in diameters increases with mean d.b.h. but does not vary with spacing.

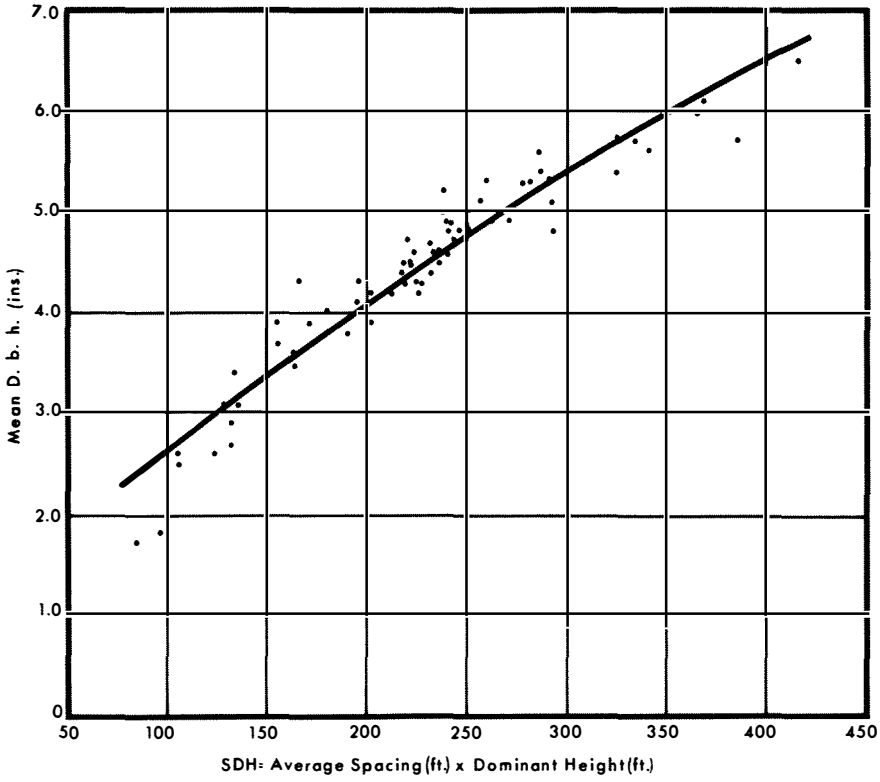


*Figure 3. Planted white spruce - relationship of mean diameter to spacing x dominant height.*

(b) The proportion of trees in the mean diameter class decreases as the stand develops, but for a given mean d.b.h. is higher at wider spacings.

(c) The number of trees below the mean diameter class is considerably greater than those above.

Stand Volume Tables

From the pooled data of all plots a good relationship between total cubic foot volume per acre and the combined height-spacing expression of dominant height/$\sqrt[3]{\text{average spacing}}$ has been determined (Stiell, 1967). Where

Vt = total volume in cubic feet per acre

HS = height-spacing expression

$Vt = -510.3 + 49.56HS + 3.356(HS)^2$ $\quad (R^2 = .993)$

Table 1. Percentage stem distribution about mean diameter class (D) in white spruce plantations

| Mean diam. class (ins.) | Spacing class (ft.) | One-inch diameter classes | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | D-5 | D-4 | D-3 | D-2 | D-1 | D | D+1 | D+2 | D+3 | D+4 | D+5 | ΣD- | ΣD+ |
| 2 | 6 x 6 | | | | | 43.1 | 51.9 | 5.0 | | | | | 43.1 | 5.0 |
| 3 | 5 x 5 | | | | 12.8 | 26.0 | 34.9 | 16.8 | 7.3 | 2.0 | 0.1 | 0.1 | 38.8 | 26.3 |
| | 6 x 6 | | | | 10.7 | 29.0 | 37.5 | 18.1 | 4.0 | 0.7 | | | 39.7 | 22.8 |
| | 7 x 7 | | | | 14.0 | 29.0 | 44.1 | 11.8 | 1.1 | | | | 43.0 | 12.9 |
| 4 | 5 x 5 | | | 3.0 | 13.9 | 24.9 | 29.5 | 17.3 | 8.3 | 2.8 | 0.3 | | 41.8 | 28.7 |
| | 6 x 6 | | | 3.2 | 12.1 | 23.3 | 30.5 | 21.0 | 7.5 | 2.1 | 0.3 | | 38.6 | 30.9 |
| | 7 x 7 | | | 2.9 | 5.6 | 20.2 | 31.8 | 29.6 | 8.7 | 1.2 | | | 28.7 | 39.5 |
| 5 | 5 x 5 | | 1.1 | 5.1 | 18.0 | 26.9 | 21.0 | 15.7 | 8.9 | 2.7 | 0.6 | | 51.1 | 27.9 |
| | 6 x 6 | | 1.3 | 8.0 | 16.9 | 23.1 | 24.0 | 15.2 | 8.0 | 2.7 | 0.6 | 0.2 | 49.3 | 26.7 |
| | 7 x 7 | | 0.8 | 4.2 | 12.2 | 21.2 | 27.2 | 21.0 | 9.5 | 3.6 | 0.3 | | 38.4 | 34.4 |
| 6 | 6 x 6 | | | 8.8 | 26.5 | 19.9 | 21.3 | 14.0 | 5.1 | 3.7 | 0.7 | | 55.2 | 23.5 |
| | 7 x 7 | 0.9 | 0.9 | 5.7 | 13.6 | 23.2 | 25.5 | 18.8 | 8.8 | 2.3 | 0.3 | | 44.3 | 30.2 |

Table 2. Stand volumes for white spruce plantations (cubic feet per acre)

| Dominant height (feet) | Volume | Average spacing (feet) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 4 | 5 | 6 | 7 | 8 | 10 |
| 20 | Total | 647 | 528 | 442 | 375 | 321 | 239 |
| | Merch. | 84 | 79 | 75 | 71 | 67 | 57 |
| 30 | Total | 1626 | 1392 | 1223 | 1092 | 988 | 831 |
| | Merch. | 1106 | 960 | 856 | 797 | 751 | 665 |
| 40 | Total | 2871 | 2485 | 2207 | 1993 | 1823 | 1567 |
| | Merch. | 2239 | 2013 | 1832 | 1714 | 1604 | 1426 |
| 50 | Total | 4382 | 3808 | 3395 | 3077 | 2826 | 2448 |
| | Merch. | 3506 | 3237 | 2954 | 2739 | 2543 | 2277 |
| 60 | Total | 6160 | 5360 | 4786 | 4346 | 3997 | 3474 |
| | Merch. | 5051 | 4556 | 4164 | 3868 | 3597 | 3231 |

The individual plot data for merchantable volume (expressed as a percentage of total volume) were pooled, and a harmonized set of curves was prepared to show change in percentage with changes in spacing and dominant height. The curves were used to determine the merchantable volumes corresponding to total volumes derived from the foregoing equation.

By using these relationships, theoretical stand volumes were "generated" for a variety of heights and spacings (Table 2). This table is useful for demonstrating what volumes would occur at given combinations of height and stocking, but of course is in no sense predictive, since it does not indicate when a plantation will reach a particular height or what the average spacing will then be.

## Yield Tables

Prediction has been attempted in Tables 3 to 6, which present total and merchantable volumes by 5-year age classes. Heights at given ages were determined from the site

index curves, and numbers of trees from the survival/height curves. Mean d.b.h. was estimated from the SDH regression. Basal areas per acre were derived by multiplying numbers of trees by the basal area equivalent to mean d.b.h. Total volumes were calculated from the HS regression. Merchantable volumes were derived as previously described. It was possible to present most values, including those for a spacing of 8 x 8 feet, without extrapolating the HS curve.

The following conclusions may be drawn from the tables:

(a) Closer spacings contain greater standing volumes at all ages than do wider spacings, although the relative difference decreases with age.

(b) Merchantable volume as a proportion of total volume increases with age, and is greater at wider than at closer spacings.

(c) Current annual volume increment culminates sooner on better sites and at closer spacings.

These tables represent probably the highest stocking that can reasonably be expected for a given planted spacing, and as such can be regarded as showing the maximum yields for which a forest manager might aim, although perhaps seldom achieve on a large scale.

Table 3. Yield table for unmanaged white spruce plantations (Site Index Class 40)

| Age from planting (years) | Dominant height (ft.) | Planted spacing (ft.) | Trees per acre | Mean d.b.h. (ins.) | Basal area (sq.ft./ac.) | Volume | |
|---|---|---|---|---|---|---|---|
| | | | | | | Total (cu.ft./ac.) | Merch. (cu.ft./ac.) |
| 20 | 17 | 4 x 4 | 2695 | 2.1 | 65 | 396 | .... |
| | | 5 x 5 | 1742 | 2.4 | 54 | 307 | .... |
| | | 6 x 6 | 1210 | 2.7 | 48 | 241 | .... |
| | | 7 x 7 | 889 | 2.9 | 41 | 189 | .... |
| | | 8 x 8 | 681 | 3.2 | 38 | 148 | .... |
| 25 | 23 | 4 x 4 | 2540 | 2.5 | 86 | 852 | 366 |
| | | 5 x 5 | 1735 | 2.9 | 80 | 730 | 314 |
| | | 6 x 6 | 1210 | 3.2 | 68 | 625 | 288 |
| | | 7 x 7 | 889 | 3.5 | 60 | 543 | 261 |
| | | 8 x 8 | 681 | 3.9 | 56 | 478 | 239 |
| 30 | 28 | 4 x 4 | 2365 | 2.9 | 109 | 1381 | 870 |
| | | 5 x 5 | 1695 | 3.3 | 100 | 1226 | 772 |
| | | 6 x 6 | 1210 | 3.6 | 86 | 1084 | 705 |
| | | 7 x 7 | 889 | 4.0 | 77 | 965 | 647 |
| | | 8 x 8 | 681 | 4.4 | 72 | 870 | 600 |
| 35 | 34 | 4 x 4 | 2150 | 3.4 | 135 | 1933 | 1450 |
| | | 5 x 5 | 1630 | 3.8 | 129 | 1762 | 1322 |
| | | 6 x 6 | 1190 | 4.2 | 114 | 1583 | 1219 |
| | | 7 x 7 | 885 | 4.6 | 102 | 1429 | 1143 |
| | | 8 x 8 | 680 | 5.0 | 92 | 1302 | 1081 |
| 40 | 40 | 4 x 4 | 1920 | 4.0 | 167 | 2563 | 2076 |
| | | 5 x 5 | 1540 | 4.3 | 156 | 2386 | 1957 |
| | | 6 x 6 | 1150 | 4.7 | 138 | 2169 | 1800 |
| | | 7 x 7 | 865 | 5.2 | 127 | 1975 | 1698 |
| | | 8 x 8 | 675 | 5.6 | 115 | 1818 | 1600 |

Table 4. Yield table for unmanaged white spruce plantations (Site Index Class 50)

| Age from planting (years) | Dominant height (ft.) | Planted spacing (ft.) | Trees per acre | Mean d.b.h. (ins.) | Basal area (sq.ft./ac.) | Volume | |
|---|---|---|---|---|---|---|---|
| | | | | | | Total (cu.ft./ac.) | Merch. (cu.ft./ac.) |
| 20 | 21 | 4 x 4 | 2605 | 2.4 | 81 | 727 | 182 |
| | | 5 x 5 | 1740 | 2.7 | 70 | 612 | 153 |
| | | 6 x 6 | 1210 | 3.0 | 59 | 518 | 150 |
| | | 7 x 7 | 889 | 3.3 | 52 | 445 | 142 |
| | | 8 x 8 | 681 | 3.6 | 48 | 386 | 135 |
| 25 | 28 | 4 x 4 | 2365 | 2.9 | 109 | 1381 | 870 |
| | | 5 x 5 | 1695 | 3.3 | 100 | 1226 | 772 |
| | | 6 x 6 | 1210 | 3.6 | 86 | 1084 | 705 |
| | | 7 x 7 | 889 | 4.0 | 77 | 965 | 647 |
| | | 8 x 8 | 681 | 4.4 | 72 | 870 | 600 |
| 30 | 36 | 4 x 4 | 2075 | 3.6 | 147 | 2096 | 1614 |
| | | 5 x 5 | 1600 | 3.9 | 133 | 1922 | 1499 |
| | | 6 x 6 | 1180 | 4.4 | 125 | 1733 | 1386 |
| | | 7 x 7 | 885 | 4.8 | 112 | 1573 | 1290 |
| | | 8 x 8 | 680 | 5.2 | 100 | 1435 | 1220 |
| 35 | 43 | 4 x 4 | 1805 | 4.2 | 173 | 2851 | 2338 |
| | | 5 x 5 | 1480 | 4.5 | 163 | 2676 | 2221 |
| | | 6 x 6 | 1110 | 5.0 | 151 | 2437 | 2096 |
| | | 7 x 7 | 850 | 5.5 | 140 | 2238 | 1969 |
| | | 8 x 8 | 665 | 6.0 | 130 | 2061 | 1855 |
| 40 | 50 | 4 x 4 | 1535 | 5.0 | 209 | 3657 | 3108 |
| | | 5 x 5 | 1330 | 5.2 | 196 | 3496 | 3007 |
| | | 6 x 6 | 1015 | 5.7 | 180 | 3211 | 2826 |
| | | 7 x 7 | 800 | 6.2 | 168 | 2976 | 2649 |
| | | 8 x 8 | 635 | 6.7 | 156 | 2765 | 2516 |

Table 5. Yield table for unmanaged white spruce plantations (Site Index Class 60)

| Age from planting (years) | Dominant height (ft.) | Planted spacing (ft.) | Trees per acre | Mean d.b.h. (ins.) | Basal area (sq.ft./ac.) | Volume | |
|---|---|---|---|---|---|---|---|
| | | | | | | Total (cu.ft./ac.) | Merch. (cu.ft./ac.) |
| 20 | 25 | 4 x 4 | 2470 | 2.7 | 99 | 1093 | 601 |
| | | 5 x 5 | 1720 | 3.0 | 84 | 952 | 524 |
| | | 6 x 6 | 1210 | 3.4 | 76 | 830 | 473 |
| | | 7 x 7 | 889 | 3.7 | 67 | 732 | 432 |
| | | 8 x 8 | 681 | 4.1 | 63 | 654 | 399 |
| 25 | 34 | 4 x 4 | 2150 | 3.4 | 135 | 1933 | 1450 |
| | | 5 x 5 | 1630 | 3.8 | 129 | 1762 | 1322 |
| | | 6 x 6 | 1190 | 4.2 | 114 | 1583 | 1219 |
| | | 7 x 7 | 885 | 4.6 | 102 | 1429 | 1143 |
| | | 8 x 8 | 680 | 5.0 | 92 | 1302 | 1081 |
| 30 | 43 | 4 x 4 | 1805 | 4.2 | 173 | 2851 | 2338 |
| | | 5 x 5 | 1480 | 4.5 | 163 | 2676 | 2221 |
| | | 6 x 6 | 1110 | 5.0 | 151 | 2437 | 2096 |
| | | 7 x 7 | 850 | 5.5 | 140 | 2238 | 1969 |
| | | 8 x 8 | 665 | 6.0 | 130 | 2061 | 1855 |
| 35 | 51 | 4 x 4 | 1500 | 5.1 | 213 | 3814 | 3280 |
| | | 5 x 5 | 1300 | 5.3 | 199 | 3643 | 3169 |
| | | 6 x 6 | 1000 | 5.8 | 183 | 3354 | 2952 |
| | | 7 x 7 | 795 | 6.3 | 172 | 3119 | 2776 |
| | | 8 x 8 | 630 | 6.8 | 159 | 2896 | 2635 |
| 40 | 60 | 4 x 4 | 1155 | 6.2 | 243 | 4717 | 4104 |
| | | 5 x 5 | 1030 | 6.4 | 230 | 4553 | 4006 |
| | | 6 x 6 | 840 | 6.9 | 218 | 4270 | 3800 |
| | | 7 x 7 | 700 | 7.3 | 204 | 4031 | 3628 |
| | | 8 x 8 | 580 | 7.7 | 187 | 3798 | 3456 |

Table 6. Yield table for unmanaged white spruce plantations (Site Index Class 70)

| Age from planting (years) | Dominant height (ft.) | Planted spacing (ft.) | Trees per acre | Mean d.b.h. (ins.) | Basal area (sq.ft./ac.) | Volume | |
|---|---|---|---|---|---|---|---|
| | | | | | | Total (cu.ft./ac.) | Merch. (cu.ft./ac.) |
| 20 | 30 | 4 x 4 | 2295 | 3.1 | 119 | 1533 | 1058 |
| | | 5 x 5 | 1680 | 3.4 | 106 | 1375 | 949 |
| | | 6 x 6 | 1210 | 3.8 | 96 | 1223 | 868 |
| | | 7 x 7 | 889 | 4.2 | 85 | 1092 | 797 |
| | | 8 x 8 | 681 | 4.6 | 78 | 988 | 751 |
| 25 | 40 | 4 x 4 | 1920 | 4.0 | 167 | 2563 | 2076 |
| | | 5 x 5 | 1540 | 4.3 | 156 | 2386 | 1957 |
| | | 6 x 6 | 1150 | 4.7 | 138 | 2169 | 1800 |
| | | 7 x 7 | 865 | 5.2 | 127 | 1975 | 1698 |
| | | 8 x 8 | 675 | 5.6 | 115 | 1818 | 1600 |
| 30 | 50 | 4 x 4 | 1535 | 5.0 | 209 | 3657 | 3108 |
| | | 5 x 5 | 1330 | 5.2 | 196 | 3496 | 3007 |
| | | 6 x 6 | 1015 | 5.7 | 180 | 3211 | 2826 |
| | | 7 x 7 | 800 | 6.2 | 168 | 2976 | 2649 |
| | | 8 x 8 | 635 | 6.7 | 156 | 2765 | 2434 |
| 35 | 60 | 4 x 4 | 1155 | 6.2 | 243 | 4717 | 4104 |
| | | 5 x 5 | 1030 | 6.4 | 230 | 4553 | 4006 |
| | | 6 x 6 | 840 | 6.9 | 218 | 4270 | 3800 |
| | | 7 x 7 | 700 | 7.3 | 204 | 4031 | 3628 |
| | | 8 x 8 | 580 | 7.7 | 187 | 3798 | 3456 |
| 40 | 70 | 4 x 4 | 845 | 7.5 | 259 | 5707 | 5079 |
| | | 5 x 5 | 780 | 7.7 | 252 | 5567 | 5010 |
| | | 6 x 6 | 680 | 8.0 | 237 | 5335 | 4802 |
| | | 7 x 7 | 580 | 8.4 | 223 | 5072 | 4616 |
| | | 8 x 8 | 515 | 8.6 | 207 | 4892 | 4452 |

## REFERENCES


ANON. 1948. Form-class volume tables. Canada Dept. Mines and Resources, Mines, Forests, and Scientific Serv. Br., Dominion For. Serv.

BERRY, A.B. 1963. Crop tree thinning white spruce plantations. Dept. of Forestry of Canada. For. Research Br. Mimeo 63-P-17.

BEEKHUIS, J. 1966. Prediction of yield and increment in *Pinus radiata* stands in New Zealand. N.Z. For. Serv., For. Research Inst., Tech. Paper No. 49.

FERGUSON, J.H.A. 1950. Enkele gegevens betreffende de ant-wikkeling van gelijkjarige *Pinus merkusii* opstanden. Bosbouwproefsta., Bogor, Java, Rapp. 34.

HILLS, G.A. and G. PIERPOINT. 1960. Forest site evaluation in Ontario. Ont. Dept. Lands and Forests, Research Br., Research Rept. No. 42.

STIELL, W.M. 1955. The Petawawa plantations. Canada Dept. Northern Affairs and National Resources, For. Br., For. Research Div., Tech. Note No. 21.

STIELL, W.M. 1965. Five year growth of thinned white spruce plantations. Woodlands Review, April.

STIELL, W.M. 1967. Plantation volume estimates from two stand parameters. Paper presented at World Symposium on Man-made Forests and Their Industrial Importance, Canberra, Australia.


1200-8-67-3.5M