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Forest Research Branch

TWENTY-YEAR GROWTH OF RED PINE PLANTED AT THREE SPACINGS

by

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Sommaire en français

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ABSTRACT

Plantations of red pine *(Pinus resinosa* Ait.*)*, established at the Petawawa Forest Experiment Station in 1941 in sandy soil of an old field at spacings of 7' x 7', 10' x 10', and 12' x 12', were examined in 1960. Detailed measurements were made to determine tree height and diameter at 5 year intervals, and observations of form-class, crown size, and branch numbers and diameters were recorded in 1960. The data are presented on the basis of average tree growth and per acre development for each spacing. Larger crowns, thicker branches, greater breast height diameters, and lower form-class were associated with wider spacing. Average height was the same at all spacings. Greater basal area and total volume per acre, and greater periodic growth of these variables were associated with closer spacing. More merchantable poles, but less pulpwood, were present at wider spacings in 1960. Planting costs at the closest spacing were estimated to be almost twice those at the widest.

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Twenty-Year Growth of Red Pine Planted at Three Spacings[1]

by

W. M. Stiell[2]

INTRODUCTION

This paper deals with the development of young red pine plantations, in relation to planted spacing, up to the time when the first silvicultural treatments might be considered, and before mutual competition has led to mortality. Long term future development and ultimate yields cannot be judged from growth in this phase, yet they will be strongly influenced by it. The general relationships presented here are not new in principle but they are specific for red pine on the sites described, and permit interim conclusions of value in plantation management.

METHODS

Establishment

In May 1941, a small spacing trial of red pine was established at the Petawawa Forest Experiment Station, near Pembroke, Ontario.[3] Two-year-old seedlings were spade-planted in ploughed furrows at exact spacings of 7' x 7', 10' x 10' and 12' x 12'. Failures were replaced with plants of the original stock for the next several years.

The site was an old field, generally level, and uncultivated for about the previous 30 years. The soil consisted of about 14 inches of sandy loam over coarse and medium sands containing much gravel and rounded stones up to 4 inches in diameter. Ground vegetation was composed mainly of thin grass sod, and a well distributed low cover of sweet fern (*Comptonia peregrina* (L.) Coult.) with somewhat less than 50 per-cent crown closure.

Measurement

In the fall of 1960 one permanent sample plot was established in each spacing condition, in areas where there had been no mortality (Table 1). Replication was impossible, since the small area suitable for sampling

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[3] Bickerstaff, A. 1942. The growth and development of red pine plantations: the effect of spacing; establishment report Project P—98. Canada, Dept. Mines and Resources, Mines, Forests, and Scientific Services Branch, Dom. For. Service. Unpub. MS.

prevented the location of more than one plot in any spacing. The following observations were made on each plot.

Height

Total height to the end of the 1960, 1955, 1950, and 1945 growing seasons was measured to the nearest foot on every tree.

Diameter

The d.b.h. of every tree was measured to the nearest 1/100-inch. Five trees in each one-inch diameter class were bored at breast height, and the 1960 radius outside bark[4], and 1960, 1955, and 1950 radius inside bark recorded. At one-half the height above breast height, the diameter outside bark and the double bark thickness (average of two samples taken with a bark gauge) were obtained for each of the same 5 trees per diameter class.

Branches

On each of the above sample trees the basal diameter of all (except dwarf) branches in the whorls closest to 0.5, 5, 9, 13, and 17 feet above the ground were measured, and the actual heights of the whorls were recorded. Living and dead branches were not tallied separately.

Crowns

The height to the base of the live crown (first wholly live whorl), the maximum width of the crown taken at right-angles to the furrow, and the height to the widest part of the crown were measured on each sample tree.

Compilation

The arithmetic average height for each plot and date was determined directly from the field measurements.

The 1955 diameter of each bored sample tree was calculated by the following steps:[5]

(a) $$\text{calculated d.i.b. 1960} = \frac{(\text{r.i.b. 1960})\,(\text{d.o.b. 1960})}{(\text{r.o.b. 1960})}$$

(b) $$\text{calculated d.i.b. 1955} = \frac{(\text{r.i.b. 1955})\,(\text{calculated d.i.b. 1960})}{(\text{r.i.b. 1960})}$$

(c) $$\text{calculated d.o.b. 1955} = \frac{(\text{d.o.b. 1960})\,(\text{calculated d.i.b. 1955})}{(\text{calculated d.i.b. 1960})}$$

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[4] r.o.b. – radius outside bark d.o.b. – diameter outside bark r.i.b. – radius inside bark d.i.b. diameter inside bark

[5] Since twice a measured radius will seldom give the same value as a measured diameter at the same point on the stem, owing to eccentricity of the growth rings, it was necessary to obtain "calculated" diameters in this manner. These computations assume a constant ratio of d.i.b. to d.o.b.

The sample trees were then divided into one-inch 1960 diameter classes, and the 1955-60 diameter growth found by subtracting the calculated 1955 diameters for each tree. Mean growth for each class was plotted over mean 1960 diameter of the class, and a free-hand curve was fitted to the points. The 1955-60 growth was then read from the curve, and this value subtracted from the 1960 measurement to give 1955 d.b.h.

Diameters for 1950 were arrived at by the same procedure. The 1950, 1955, and 1960 diameters were summarized by one-inch classes, and the average d.b.h. for each year calculated by the basal area method.

The 1960 form-class[6] was determined for each of the sample trees, and straight-line regressions of form-class on d.b.h. calculated for each plot.

The 1950, 1955 and 1960 per acre values were computed for basal area, total volume, and merchantable volume (of trees over 3.5 inches d.b.h.). Volumes were compiled from Form-Class Volume Tables (Dominion Forest Service 1948), with the tabular values modified by the ratio of 1960 average form-class/form-class 70.

Dry foliage weights of sample trees were estimated from the formula derived by Stiell (1962):—

Weight in grams = (10.62) (cubic foot volume of the crown considered as a paraboloid) + 1403.5.

Regressions of foliage weight on d.b.h. were calculated, and from these the weight of foliage per acre was estimated for each plot. The error associated with the source equation was not incorporated in these calculations.

Average branch diameters and numbers were computed according to height above ground and d.b.h. class.

RESULTS

Stem Growth

The fewer the trees per acre, the greater was the diameter at breast height. This is exemplified by mean d.b.h. which was consistently greater at wider spacings for all dates (Table 1 & Figure 1), and by the diameter distributions (Table 2). Diameter growth rates declined somewhat on each plot in the period 1955-60. In 1950 and 1955, diameters at the 12' x 12' and 10' x 10' spacings were fairly similar, but at the 10' x 10' spacing growth fell off considerably after 1955.

Mean height was remarkably similar on all plots for the same ages, showing no association with spacing. Even on the basis of the 200 tallest trees per acre, which might form the final crop, heights at the different spacings did not differ by more than one foot for a given age. Mean and

[6] Ratio of the d.i.b. at half the tree height above breast height to d.i.b. at breast height.

TABLE 1: BASIC PLOT DATA

		Spacing, feet		
		7 x 7	10 x 10	12 x 12
Plol size, acres		0.125	0.167	0.333
Trees per plot		121	77	103
Trees per acre	1945–1960	968	462	309
Average d.b.h., in	1950	1.7	2.0	2.1
	1955	3.6	4.5	4.8
	1960	5.3	6.5	7.3
	Annual growth 1950–1955	0.4	0.5	0.5
	1955–1960	0.3	0.4	0.5
Basal area (tree of av. d.b.h.) sq. ft.				
	Annual growth 1950–1955	0.011	0.018	0.020
	1955–1960	0.016	0.024	0.033
Form-class (tree of av. d.b.h.) %	1960	57.9	51.3	48.4
Average height, ft.	1945	2.9	2.8	3.1
	1950	10.4	10.1	10.8
	1955	20.0	19.9	20.6
	1960	30.2	30.5	31.3
	Annual growth 1950–1955	1.9	2.0	2.0
	Annual growth 1955–1960	2.0	2.1	2.1
Height to living crown (tree of av. ht.) ft.	1960	12.6	8.2	6
Crown length (tree of av. ht.) %	1960	58.5	73.0	80.8
Dry foliage weight (tree of av. d.b.h.) kilos.	1960	7.8±1.0	11.6±1.4	15.6±2.3
Dry foliage weight (per ac.) kilos	1960	7,446±958	5,326±627	4,742±700
Basal area, sq. ft. per ac.	1950	16	10	8
	1955	*70	51	39
	1960	150	107	89
	Annual growth 1950–1955	*10.8	8.2	6.2
	Annual growth 1955–1960	16.0	11.2	10
Total volume, cu. ft. per ac.	1950	92	52	34
	1955	*656	412	296
	1960	1,905	1,168	940
	Annual growth 1950–1955	*112.8	72.0	52.4
	Annual growth 1955–1960	249.8	151.2	128.8
Merchantable volume (trees over 3.5" d.b.h.) cu. ft. per ac.	1950	0	0	0
	1955	254	210	155
	1960	1,194	833	710
	Annual growth 1955–1960	188	124.6	111

* includes ingrowth of 16 trees per acre 1950–1955

TABLE 2; DIAMETER DISTRIBUTION OF TREES GREATER THAN 0.5 INCHES D.B.H., TREES PER ACRE.

Diameter Class, inches	Spacing, feet								
	7' x 7'			10' x 10'			12' x 12'		
	1950	1955	1960	1950	1955	1960	1950	1955	1960
1	224	8	-	6	-	-	3	-	-
2	728	96	-	432	6	-	267	3	-
3	-	256	40	24	-	6	39	3	3
Sub Total	952	360	40	462	6	6	309	6	3
4	-	496	184	-	222	-	-	78	-
5	-	112	280	-	222	54	-	195	3
6	-	-	424	-	12	126	-	30	36
7	-	-	40	-	-	258	-	-	168
8	-	-	-	-	-	18	-	-	93
9	-	-	-	-	-	-	-	-	6
Sub Total	-	608	928	-	456	456	-	303	306
Total	952	968	968	462	462	462	309	309	309

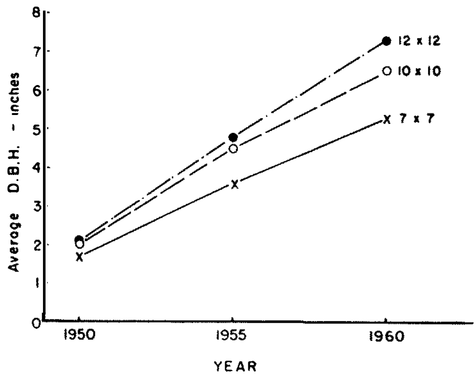

Figure 1. Growth in mean diameter.

dominant height growth accelerated during 1950-55 and maintained their rates 1955-60. From the foregoing it is apparent that for a given diameter, height is greater at closer spacings (Figure 2).

Greater average form-class was associated with closer spacing. However there was considerable variation within each spacing, and form-class showed no significant relationship to d.b.h. (Figure 3).

Foliage

Crowns at the 12' x 12' spacing had not closed by 1960; those of adjacent trees at 10' x 10' were just making contact; and those at 7' x 7' had evidently closed several years previously.

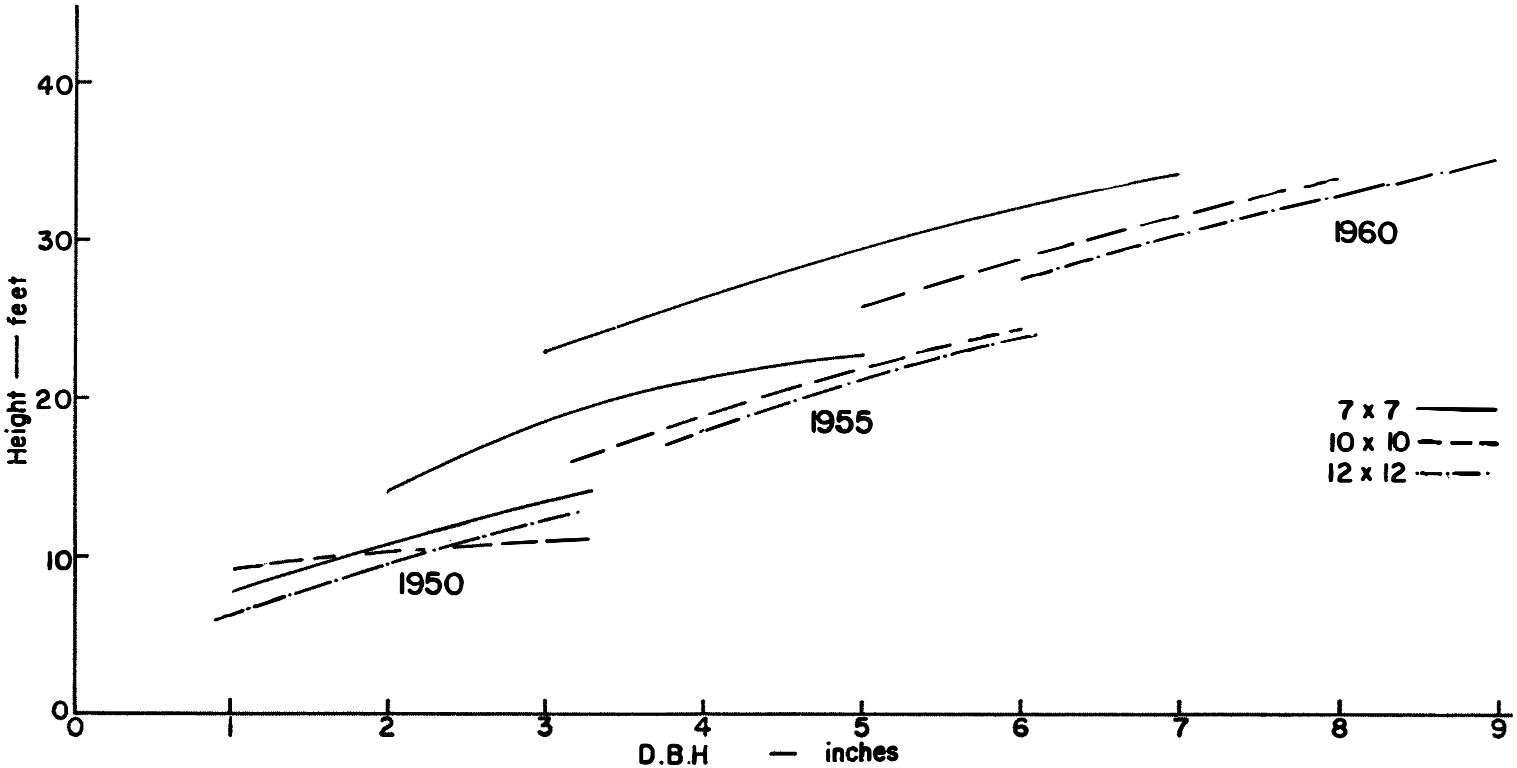

Figure 2. Height-diameter relationship.

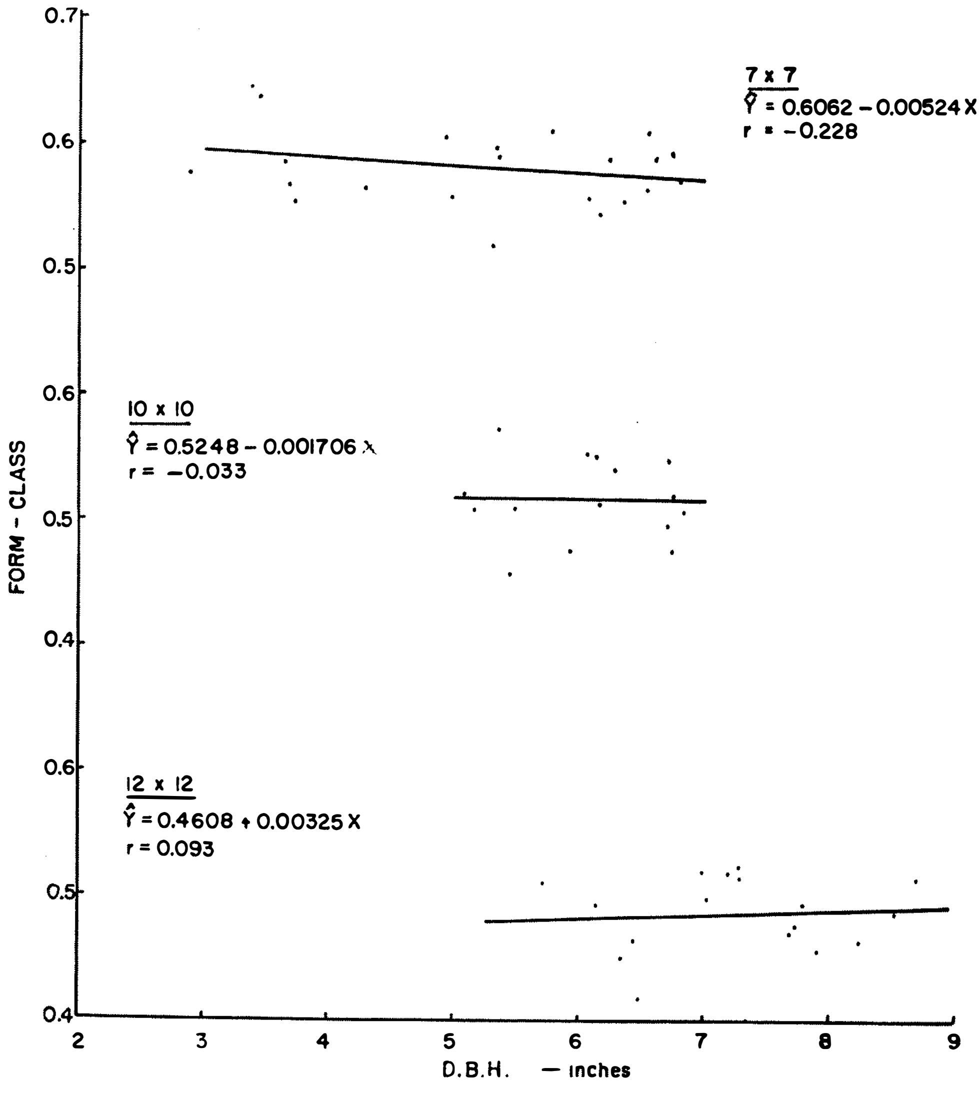

Figure 3. Regression of form-class on d.b.h. (o.b.)

Crown length and foliage weight of the tree of average diameter increased with spacing. Height to crown showed an increase with increasing d.b.h. at the 7' x 7' and 12' x 12' spacings, but there was no apparent relationship between these two variables at 10' x 10'. Within diameter classes there was much variation in height to crown at all spacings.

The straight-line regressions of foliage weight in grams (W) on d.b.h. in inches (D) for each spacing showed a correlation (r) significant at the one per cent level, as follows:

7' x 7' - W - 2,083.2D - 3,248 (r=0.939)
10' x 10' - W - 5,312.7D - 5,312 (r=0.789)
12' x 12' - W - 3,699.1D - 11,372 (r=0.823)

However when the data from all spacings were pooled, the relationship proved to be curvilinear. Transformation to logarithmic values produced a straight line (Figure 4), represented by an equation of the type described by Kittredge (1944):

$$\log W = 1.783 \log D - 0.383 \quad (r=0.946)$$

Despite the larger individual crowns, weight of foliage per acre was less at wider spacings.

Branches

The number of branches per whorl was apparently independent of d.b.h. and spacing; it increased with height above the ground up to about breast height, remaining more or less constant above there (Figure 5).

Table 3 shows average branch diameter at various heights above ground. Within spacings branch size showed a slight increase with increasing d.b.h. Branch diameter increased also with height above ground to between 6 and 9 feet, beyond which it remained more or less constant. For trees of the same d.b.h., branch diameter increased slightly with spacing. As a result branch diameters of the tree of average d.b.h. were much greater at wider spacings, e.g. at 17 feet above the ground, average branch size was 0.91 inches at 7' x 7', 1.11 inches at 10' x 10', and 1.19 inches at 12' x 12' (Figure 6).

TABLE 3: BRANCH DIAMETERS

D.b.h. class-inches	Height above ground, - feet														
	0.5			5			9			13			17		
	Spacing – feet														
	7	10	12	7	10	12	7	10	12	7	10	12	7	10	12
	Average branch diameter-inches														
3	0.49	-	-	0.56	-	-	0.63	-	-	0.60	-	-	0.59	-	-
4	0.64	-	-	0.74	-	-	0.82	-	-	0.75	-	-	0.64	-	-
5	0.65	0.79	-	0.77	1.03	-	0.84	0.90	-	0.89	0.96	-	0.94	0.96	-
6	0.60	0.87	0.80	0.87	1.04	1.16	0.89	0.96	1.04	0.92	1.16	1.05	1.00	1.00	0.99
7	0.67	0.79	0.81	0.87	1.09	1.18	1.02	1.07	1.14	1.01	1.21	1.29	1.07	1.15	1.25
8	-	-	0.93	-	-	1.22	-	-	1.20	-	-	1.18	-	-	1.10
9	-	-	0.87	-	-	1.46	-	-	1.37	-	-	1.20	-	-	1.40
Average	0.61	0.82	0.85	0.76	1.05	1.25	0.84	0.98	1.19	0.83	1.11	1.18	0.85	1.04	1.18

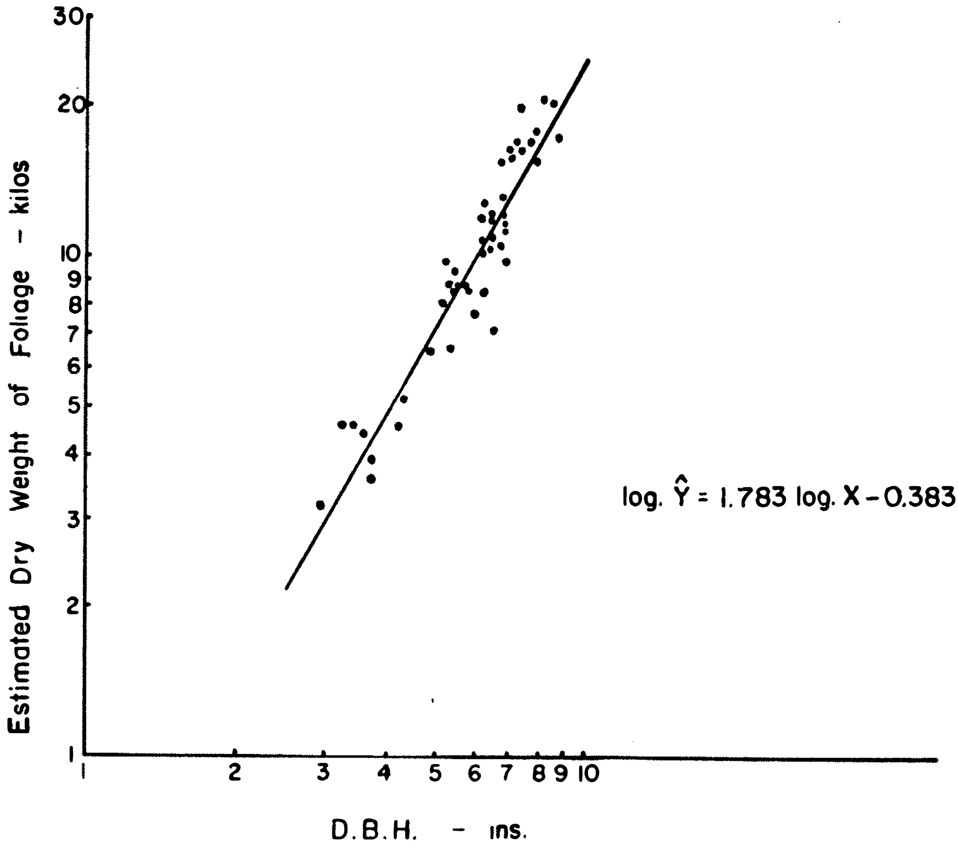

Figure 4. Foliage weight – d.b.h. relationship.

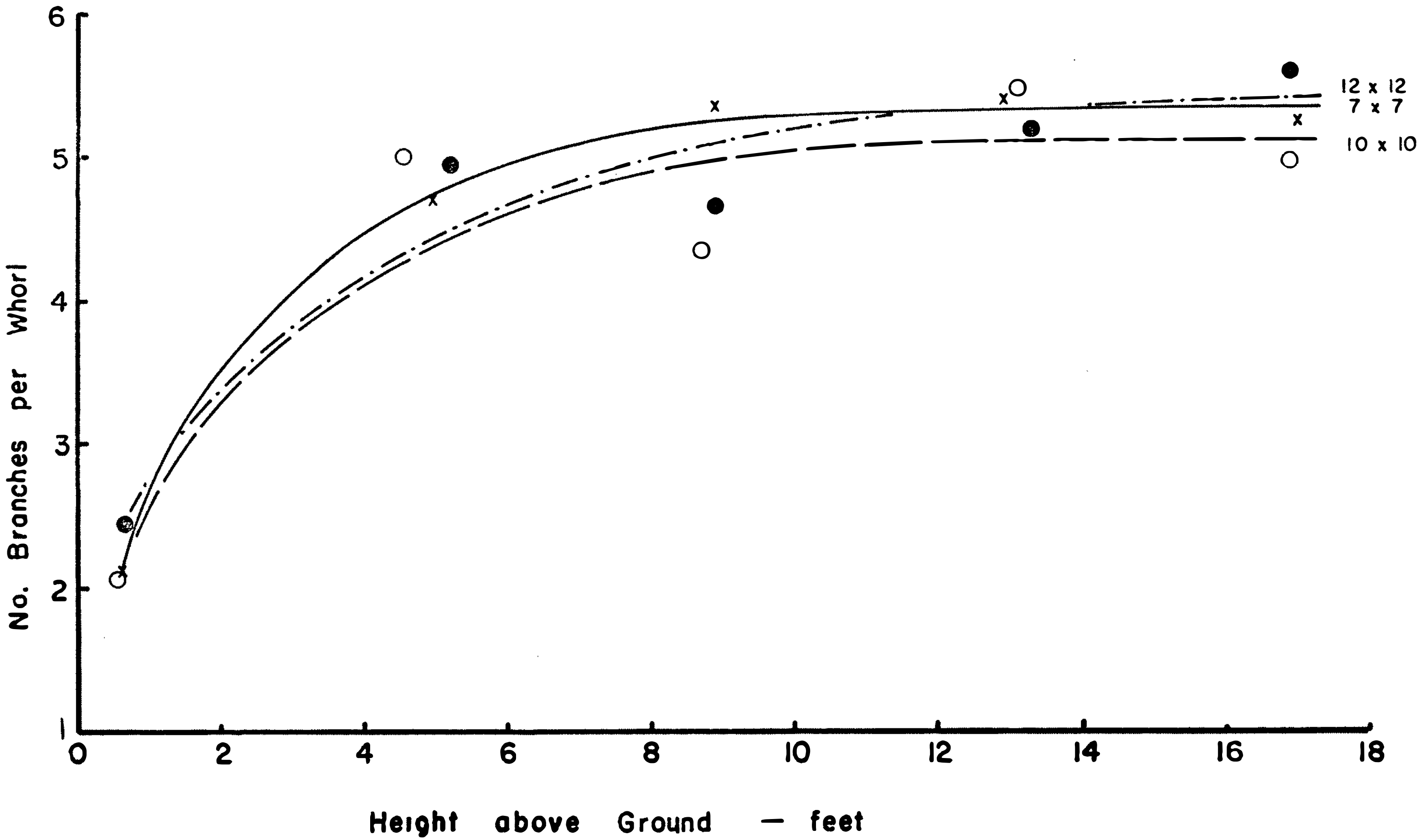

Figure 5. Relationship of branch number per whorl to height above ground.

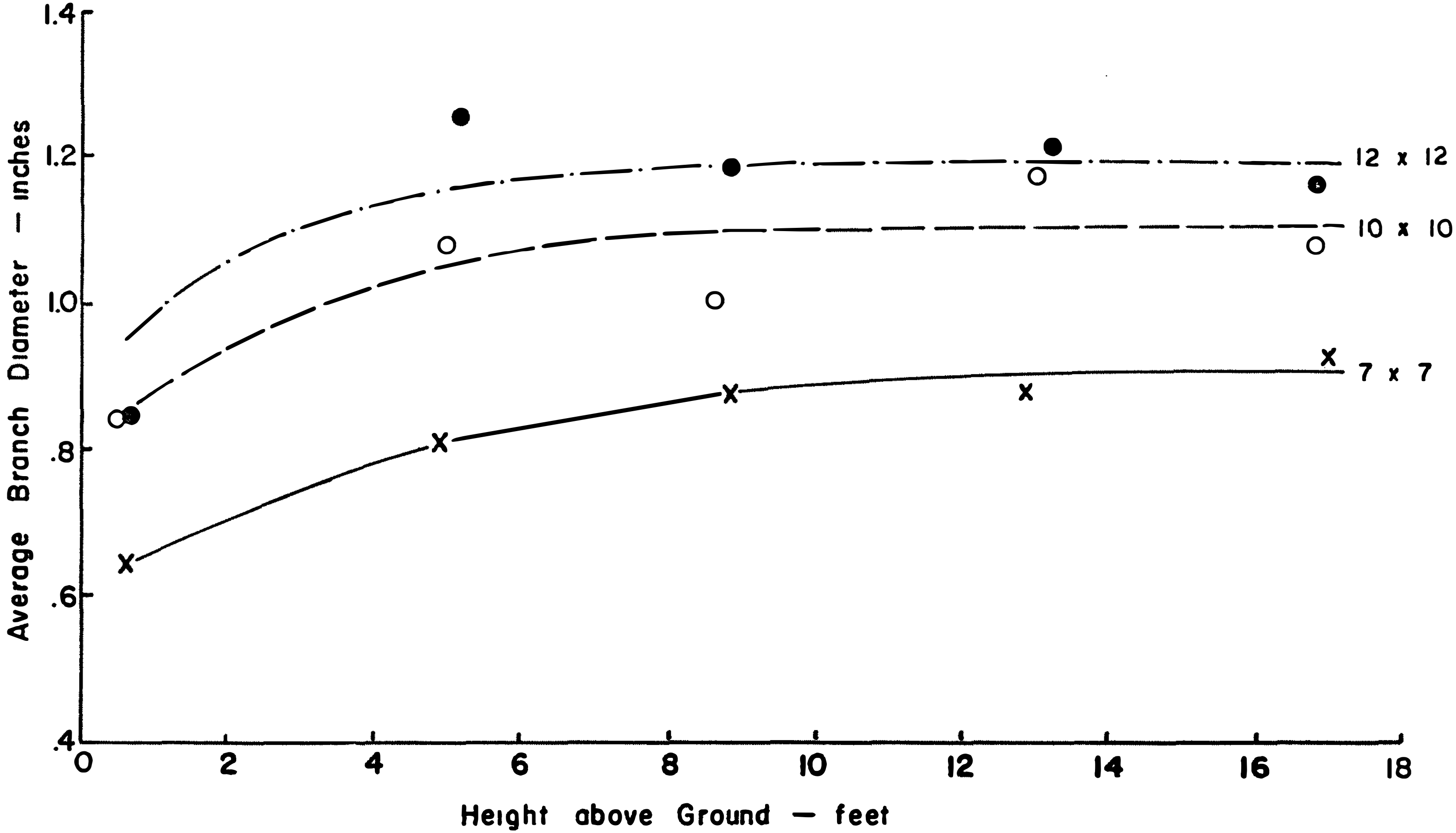

Figure 6. Relationship of average branch diameter to height above ground for tree of average diameter.

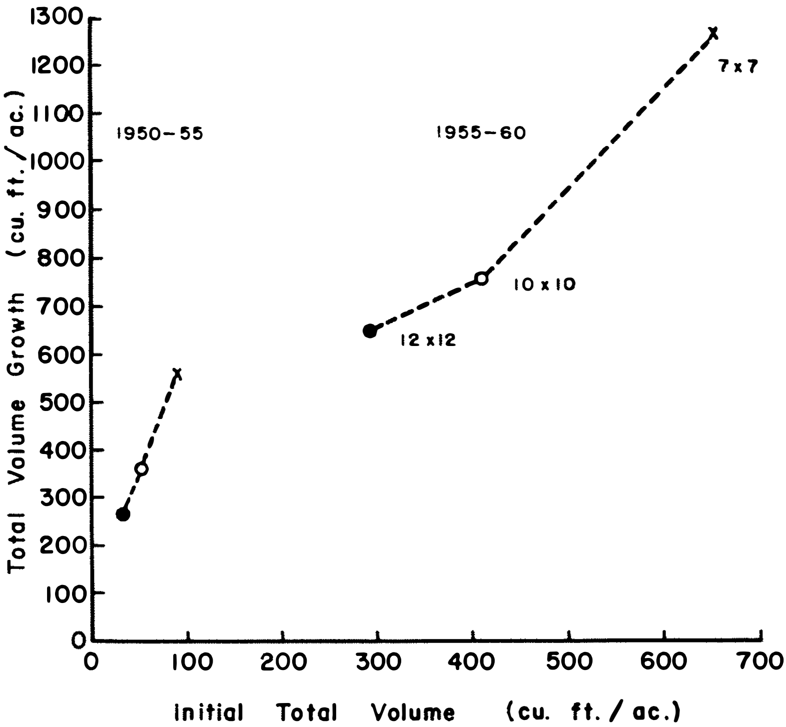

Figure 7. Periodic total volume increment.

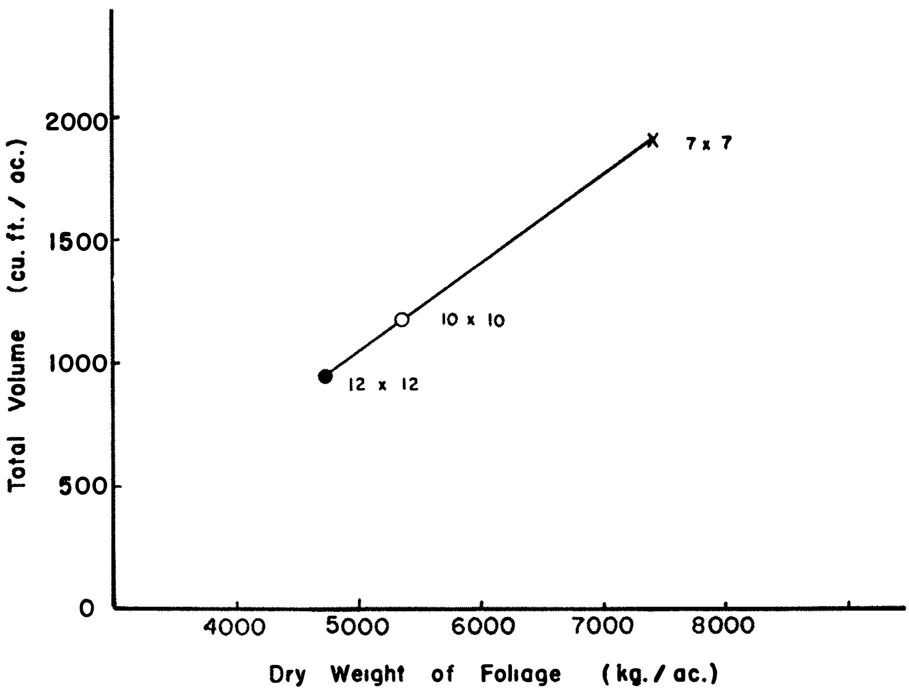

Figure 8. Total volume foliage relationship, 1960.

Per Acre Development

Greater basal area and greater basal area increment were at all times associated with closer spacing. The 7' x 7' spacing showed an advantage in this respect even before the ingrowth of trees less than 0.5 inches d.b.h. occurred in the period 1950-55. Growth rates accelerated during 1955-60 in all cases, with the 7' x 7' spacing increasing its lead over the 10' x 10', but with the 12' x 12' growing almost as rapidly as the 10' x 10'.

Total volume showed a parallel development, with greater volumes present at each date and greater increment in both periods being associated with closer spacing. Volume growth rates also accelerated during 1955-60 (Figure 7).

No trees over 3.5 inches d.b.h., and therefore no merchantable cubic volume, were present at any spacing before 1955. Thereafter the closer the spacing the greater was the volume, but in no case was ingrowth complete by 1960.

DISCUSSION

Growth of the Tree

Even the incompletely closed crowns at 12' x 12' admitted too little light to sustain the lower whorls, and under the denser canopies of the other spacings branch mortality proceeded more rapidly up the stem. The prime consequence of wider spacing is evidently that the additional light available permits branches to remain alive and grow for longer periods, producing a greater weight of foliage per tree for a given age. Variable crown length within a diameter class is attributed to the erratic course of mortality at the base of the crown as opposed to the annual addition of a new whorl at the apex (Stiell 1962).

For the individual tree, the most evident result of a larger crown is greater breast-height diameter growth at wider spacings, a generally accepted development. However greater d.b.h. is not accompanied by relatively greater diameter at half height above breast-height. Since the concentration of stem growth lower down the tree is associated with longer crowns, it appears that a greater proportion of wood is laid down in the vicinity of the live crown. This process is likely most pronounced near the zone of maximum crown width, as observed in loblolly pine *(Pinus taeda* L.*)* by Labyak and Schumacher (1954). A second result of greater spacing, then, is lower average form-class. The considerable form-class variation within spacings of trees of similar d.b.h., which has been observed in other red pine plantations at Petawawa and elsewhere (Stiell 1960), is most likely due to the variable crown length referred to above.

Unlike d.b.h., height has not been affected by spacing, and it must be presumed that at the closest spacing the crowns are not yet short enough to reduce optimum height growth. Slabaugh (1957) found a slight decrease in height growth when pruning reduced red pine live crown ratios to 70 per cent, but the loss was small even down to a ratio of 50 per cent. The average ratio at 7' x 7' between 1955 and 1960 must have been at least 60 per cent and apparently still adequate to maintain normal height increment. Probably a more meaningful index, where the comparison is between stands of different stocking, would be the ratios of foliage weight (grams) to height (feet) – respectively 258, 380, and 498 for the 7' x 7', 10' x 10', and 12' x 12' spacings.

Despite a falling rate of diameter growth at 7' x 7' and 10' x 10' during 1955-60, average rate of basal area growth per tree increased in this period. Since height growth was virtually unchanged over the same time, basal area growth was the main determinant for volume increment. Hence the rate of volume growth per tree increased 1955-60, with faster growth occurring with wider spacing, despite lower form class.

Spacing could hardly be expected to affect the numbers of branches per whorl, since lateral buds are initiated at the apex of the tree under uniform conditions of light, irrespective of the light received further down the crown. Larger branch diameters at wider spacings are simply due to greater branch age and the additional increment put on during the extra years. Branch thickness is important from the utilization standpoint. Natural pruning evidently will not occur at any of these spacings in a reasonable time, and production of clear lumber would require manual pruning. Pruning a given number of trees per acre would take slightly longer at wider spacings owing to the thicker branches. The most valuable products in red pine plantations are poles, and pole specifications do not permit knot diameters in any one-foot section to aggregate more than 8 inches (Canadian Standards Association 1960). The largest combination of branch diameter and number was 7.0 inches at 7' x 7'; 8.2 inches at 10' x 10'; and 9.6 inches at 12' x 12'. At each of the wider spacings about 20 per cent of the trees large enough for utilization as poles would be disqualified for this purpose because of knot size.

Growth of the Stand

Greater volumes were associated with closer spacings at all dates. According to Braathe (1957) this is common experience with European spacing trials, and he attributes the lower volumes at wider spacings to incomplete soil utilization up to the time of stand closure. The crowns would have been closed by 1955 at 7' x 7', but would still have been very open at the wider spacings. Hence with incomplete closure, and therefore incomplete utilization of the site, the principle of similar basal area and volume growth over a wide range of stand densities (see Mar: Moller 1954) presumably would not apply (Figure 7). Basal area growth during 1955-60 at 7' x 7' was very close to the maximum (15 square feet per acre per year) cited by Morrow (1961) for unthinned red pine stands during the first few years after closure. In the same period increased growth at the wider spacings indicated improved use of the site.

Growth is no doubt largely dependent on the supply of foliage, and probably a given quantity of foliage is required to produce a given volume of wood. Although some photosynthate will be utilized in branch and root formation, a relationship should exist between the average amount of foliage present per acre for a given period and stem wood formed in the same time. No values for foliage in the past are available, and only future remeasurement can confirm this hypothesis. Figure 8 shows a remarkably consistent apparent association between foliage per acre and total volume in 1960.

Utilization

It is clear that trees of larger diameter and volume were produced at a given age at wider spacings, suggesting the possibility of earlier utilization for such products as poles and sawlogs. The question arises, however, whether the faster grown trees may have poorer strength properties, owing to a larger amount of juvenile core wood. This wood, which is laid down for a period of years next to the pith and is characterized by low specific gravity and low strength for its specific gravity (Scott and MacGregor 1952), occurs in many species (Besley 1960). According to Rendle and Phillips (1958) the change from low density juvenile to adult wood is related to distance from the pith as measured by rings (age) rather than by inches, and usually occurs between 10 and 20 years of age probably regardless of rate of growth (Phillips 1962). Thus the diameter of the juvenile core is chiefly a function of age, and trees that have grown more quickly in early life will have a larger core. Morrow (1961) considers that juvenile core wood in red pine will have little effect on quality, since it represents so little volume. Actual strength properties have not been determined for wood in this study, but if it is assumed that the change to mature wood at breast height occurred at an average age of 10 years, then the following calculations may help elucidate the problem for the widest and closest spacings:

	7' x 7'	12' x 12'
Basal area of tree of average d.b.h. 1955 (=core), sq. ft.	.075	.126
Basal area of tree of average d.b.h. 1960, sq. ft.	.153	.291
Basal area growth 1955-60, sq. ft.	.078	.165
Basal area of core as % of 1960 b.a.	49.0	43.4

Therefore at 12' x 12', the average tree has a larger juvenile core at breast height but also has more mature wood and a slightly smaller proportion of core wood. Considering trees of the same diameter in 1960, e.g. 5.3 inches (average diameter at 7' x 7' used above), and deducting the 1955-60 growth for that class at the 12' x 12' spacing, then:–

	12' x 12'
Basal area 1955 (=core), sq. ft.	.056
Basal area 1960, sq. ft.	.153
Basal area growth 1955-60, sq. ft.	.097
Basal area of core as % of 1960 b.a.	36.6

Thus for trees of the same 1960 d.b.h., the breast-height core at 12' x 12' is both actually and by per cent smaller than at 7' x 7'. This suggests that the amount of core wood, as related to spacing, would have no great effect on strength properties.

The most valuable products yielded from thinning red pine plantations are poles. By 1960 all spacings contained poles of minimum usable length and top diameter, and with acceptable knot size (Canadian Standards Association 1960).Numbers of poles increased with spacing (Table 4).

TABLE 4: AVAILABLE 16-FOOT POLES*, 1960

D.b.h. class, inches	Spacing, feet		
	7 x 7	10 x 10	12 x 12
7	40	38	24
8	-	14	74
9	-	-	3
TOTAL	40	52	101

* Class 10 - minimum top diameter 3.82 inches

The first merchantable material produced in young plantations is pulpwood. Here also the extent of the juvenile core may be important. Core material of loblolly pine and slash pine *(Pinus elliotti* var. *elliotti* Engelm.) is characterized by short fibres and low cellulose content (Besley 1960). If similar features prevail in red pine, the pulp yield from a tree of given size would be greater at wider spacings. Calculations similar to those made above indicate that in 1960 the volume and proportion of core wood per acre were greater at 7' x 7' than at 12' x 12', and presumably this relationship between spacings would continue if the stands remained unthinned. On the other hand, owing to its greater merchantable volume per acre and denser mature wood, the 7' x 7' stand would be expected to have produced the greatest pulp yield; yields from the other two spacings would probably differ little.

Stumpage values (Table 5) have been calculated for local timber dues (Anon 1962). The highest value at 7' x 7' is due to the larger amount of pulpwood. Values at the wider spacings reflect the greater number of poles and the much better price paid for these products.

TABLE 5: STUMPAGE VALUES PER ACRE 1960

	Spacing, feet		
	7 x 7	10 x 10	12 x 12
Pulpwood at $2./cord*	$24.60	$15.80	$ 9.60
Poles at $0.05/cubic foot	4.57	6.09	14.00
TOTAL	$29.17	$21.89	$23.60

* 90 merchantable cubic feet

It would be instructive to compare stumpage values with planting costs, but unfortunately the latter were not recorded. In Table 6 the cost of planting stock is based on Ontario Department of Lands & Forests' nursery prices, and man-days for planting an acre at different spacings (derived from Davis, Ferree, and Stout 1952) are combined with local wage rates to give labour costs. These values are simply the basic cost items and do not take into account supervision, transportation, etc.; nevertheless they should indicate relative planting charges, according to spacing.

TABLE 6: BASIC PLANTING COSTS PER ACRE (ESTIMATED), TO 1960

	Spacing, feet		
	7 x 7	10 x 10	12 x 12
Planting stock at $10./ thousand plants	$ 9.68	$ 4.62	$ 3.09
Labour at $10.80/man-day	23.54	17.82	15.98
TOTAL	$33.22	$22.44	$19.07
Compounded at 4% for 20 years	$72.78	$49.17	$41.78

There would obviously be no point in clear-cutting such young stands. There would be little in thinning them either, considering their accelerating growth rates and high potential for pole production. It would not be too soon to prune crop trees to be utilized eventually as sawlogs, and in this respect a light thinning might be desirable in the 7' x 7' spacing to help maintain diameter growth of these trees and to partially offset pruning costs. The latter are always a direct outlay made in the expectation of future increased values. Pruning 200 trees per acre to a height of 17 feet would take about 25 man-hours (Berry 1963) and cost about $34.00. If another 200 trees per acre were removed they would yield about 2.5 cords, or $5.00 in stumpage.

CONCLUSIONS

The wider spacings appear to offer the best possibilities of an early net return. Under present standards of utilization the small sizes attained at 7' x 7' in 20 years are of little commercial value, yet vigorous diameter growth can only be maintained by an early thinning. At 10' x 10' pruning costs will be slightly higher owing to larger, and additional living, branches, but good diameter growth could be expected for at least another 10 years, when a profitable pole cut could be made. At 12' x 12' the current rate of value increment should be high, and perhaps larger diameters would temporarily compensate for the per acre growth loss in smaller merchantable sizes, permitting a short-term recovery of the planting investment.

A normal rotation required to grow the large-sized products in which red pine commands the highest price would present a different financial picture, with the likelihood of greater profits. Over this period the close spacing could be expected to yield more material (although of smaller average size) in thinnings. On the other hand, the wider spacings would produce sawlogs or piling of given dimensions in a much shorter time, and the accumulated planting costs to be recovered would be much lower. The respective margins of profit will finally be determined by balancing these considerations, but cannot be predicted from the present stage of stand development.

SUMMARY

1. In May, 1941 a spacing trial of red pine was established at the Petawawa Forest Examination Station. Two-year-old seedlings were planted in ploughed furrows at 7' x 7', 10' x 10', and 12' x 12'. The site was an old field covered with a thin grass sod. The soil consisted of about 14 inches of sandy loam over medium and coarse sands, containing much gravel and small rounded stones.

2. In the fall of 1960 one plot was established in each spacing. Detailed measurements were taken of present and past (at 5-year intervals) heights and diameters, and of present form-class, crown size, and branch development.

3. Spacing relationships with the above variables, and with basal area and total merchantable volume, were examined in detail.

4. Estimates were made of current stumpage values and accumulated planting costs for each spacing.

5. Stumpage values calculated for local timber dues were highest for the 7' x 7' spacing owing to the much larger pulpwood volume in this stand. Much of this value was compensated for at 12' x 12' by the more numerous, higher priced, pole stock.

6. Estimated planting costs, compounded at 4 per cent for 20 years, were in the ratio of 1: 1.2: 1.7 for the 12' x 12', 10' x 10', and 7' x 7' spacings respectively. These costs greatly exceeded current stumpage values.

7. It is suggested that about 200 crop trees per acre should be pruned at all spacings. The 7' x 7' stand should also be thinned to help maintain a good diameter growth and to partially offset pruning costs.

8. The wider spacings seem to offer better possibilities of an early net return, but the most profitable spacing over a rotation required to grow large and high-priced products cannot be judged at this time.

SOMMAIRE

1. En mai 1941, une expérience d'espacement de plants de pin rouge a été entreprise à la Station d'expérimentation forestière de Petawawa. Des semis de deux ans furent plantés dans des sillons de charrue, à intervalles de 7 pieds, de 10 pieds et de 12 pieds, dans le rang et transversalement. Le terrain était un ancien champ cultivé recouvert d'un mince gazon. Le sol se composait de 14 pouces de limon sableux recouvrant un horizon de sable moyen et de sable grossier mêlé de gravier et de petits galets.

2. Au cours de l'automne de 1960, on a établi un placeau-échantillon dans chacune des aires d'essai d'espacement. On a pris les mesures exactes, passées et présentes, à cinq années d'intervalle, de la hauteur et du diamètre des arbres, ainsi que celles de leur catégorie de forme, du volume des houppiers et de la croissance des branches en 1960.

3. Le rapport entre l'espacement et les données ci-dessus, la surface terrière et le volume de bois marchand ont été étudiés en détail.

4. On a calculé la valeur estimative du bois sur pied et les frais généraux de plantation pour chaque espacement.

5. La valeur du bois sur pied, calculée d'après les prix locaux, était la plus élevée dans le cas des arbres plantés à 7 pieds d'intervalle, à cause d'un beaucoup plus fort volume de bois à pâte dans ce genre de peuplement. Dans le cas des arbres plantés à intervalles de 12 pieds, la moins-value en bois à pâte était compensée par la plus-value des arbres à poteaux, plus nombreux et plus chers.

6. Le coût estimatif de plantation, calculé à raison de 4 p. 100 pendant 20 ans, s'établissait à 1, 1.2 et 1.7 pour les arbres plantés à 12 pieds, 10 pieds et 7 pieds d'intervalle, respectivement. Les frais d'exploitation dépassaient de beaucoup la valeur du bois sur pied.

7. Il est recommandable d'élaguer 200 sujets choisis par acre, quel que soit l'espacement choisi. Les peuplements d'arbres plantés à 7 pieds d'intervalle devraient être éclaircis, afin de favoriser la croissance en diamètre et de compenser ainsi une partie des frais d'élagage.

8. La plantation des arbres à plus grand intervalle semble offrir de meilleurs avantages prochains; toutefois, l'espacement le plus avantageux en ce qui concerne la production d'arbres de fort volume et de grande valeur marchande reste encore à déterminer.

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