SPACING EFFECTS 15 YEARS AFTER PLANTING THREE CONIFERS IN MANITOBA

I.E. BELLA and J.P. DE FRANCESCHI

INFORMATION REPORT NOR-X-223
MARCH 1980

NORTHERN FOREST RESEARCH CENTRE
CANADIAN FORESTRY SERVICE
ENVIRONMENT CANADA
5320 - 122 STREET
EDMONTON, ALBERTA, CANADA
T6H 3S5

Bella, I.E. and J.P. De Franceschi. 1980. Spacing effects 15 years after planting three conifers in Manitoba. Environ. Can., Can. For. Serv., North. For. Res. Cent. Edmonton, Alberta. Inf. Rep. NOR-X-223.

ABSTRACT

Jack pine (*Pinus banksiana* Lamb.), red pine (*Pinus resinosa* Ait.), and white spruce (*Picea glauca* (Moench) Voss) were planted at 1.2-, 1.8-, 2.4-, and 3.0-m spacings in 11 X 11 matrices with four replications in the Sandilands Forest Reserve in Manitoba. Measurements were taken in 1978, 16 growing seasons after planting.

Diameter increment in terms of basal area was over 100% greater for wide than for narrow spacings, which gave rise to substantial differences in average diameter. At wide spacing, red pine surpassed jack pine by a small amount. Height growth was reduced with increasing spacing in jack pine but was unaffected in red pine. The average height of white spruce was less than half that of the pines. Jack pine developed poor tree form and heavy branches at wide spacings, while red pine showed little adverse effect. Mortality was low. Stand productivity—whether in basal area, volume, or biomass—was highest at the closest spacing, but continued faster growth at wide spacing means that the difference will be reduced or even eliminated by rotation age. Recommendations are given on spacing and species selection for future planting of conifers in southeastern Manitoba.

RESUME

Le Pin gris (*Pinus banksiana* Lamb.), le Pin rouge (*Pinus resinosa* Ait.), et l'Epinette blanche (*Picea glauca* (Moench) Voss) ont été plantés aux espacements de 1,2-, 1,8-, 2,4-, et 3,0-m en matrices de 11 X 11 et quatre répétitions, dans la réserve forestière de Sandilands au Manitoba. Des mesurages ont été effectués en 1978, 16 ans après le plantage.

L'accroissement du diamètre en termes de surface terrière s'est avéré 100% meilleur dans les grands espacements que dans les faibles espacements, ce qui a occasionné des différences substantielles du diamètre moyen. Dans les matrices à fort espacement, le Pin rouge a dépassé quelque peu le Pin gris. La croissance en hauteur a diminué en fonction inverse de l'espacement chez le Pin gris mais n'a pas changé chez le Pin rouge. La croissance moyenne en hauteur de l'Epinette blanche était moins de la moitié de celle des Pins. Le Pin gris dans les matrices à fort espacement a développé un port médiocre et des branches lourdes, tandis que le Pin rouge n'a accusé que de faibles effets adverses. La mortalité a été faible. La productivité du peuplement quant à la surface terrière, au volume ou à la biomasse s'est avérée meilleures dans les matrices à faible espacement, mais la plus rapide croissance continue dans celles à fort espacement signifie que la différence sera réduite ou même éliminée à l'âge de révolution. Des recommandations sont faites au sujet de l'espacement ainsi que du choix des essences pour les plantations futures de conifères dans le sud du Manitoba.

CONTENTS

FIGURES

TABLES

INTRODUCTION

Initial spacing of trees has a major effect on subsequent growth, yield, and quality of wood produced as well as on the cost of planting and subsequent management practices. As planting increases in importance across Canada, information on these relationships is urgently required for intelligent management of plantations. The Canadian Forestry Service in cooperation with the Manitoba government initiated a study in 1962 to obtain information on growth, development, and yield of three important commercial indigenous conifers at various practical spacings on some of the major site types in Manitoba.

An earlier report (Bella and De Franceschi 1974) provides some background and the general objectives for the study as well as growth results for the first decade after planting. This report presents the results of the second assessment 15 years after planting and covers primarily jack pine (*Pinus banksiana* Lamb.) and red pine (*Pinus resinosa* Ait.). White spruce (*Picea glauca* (Moench) Voss) had much slower initial growth and showed no spacing effects at this range of densities, so it is mentioned only briefly in this report.

DESCRIPTION OF STUDY AREAS

The study has two locations: near Moodie in the Sandilands Forest Reserve, and in Riding Mountain National Park.

At Moodie, jack pine is the dominant coniferous species, and the forest belongs to the Rainy River Section L.12 of the Great Lakes-St. Lawrence Region (Rowe 1972). At Riding Mountain, white spruce is the dominant coniferous species; this area is in the Mixedwood Section B.18a of the Boreal Forest Region (Rowe 1972).

At Moodie the soils are sandy and nutritionally poor with a fresh moisture regime (Mueller-Dombois 1964). Topography is flat. The planting site is located on an abandoned field where grasses and low shrubs have formed a dense sod. Furrows were ploughed to prepare the ground for planting. At Riding Mountain the planting site was on calcareous till with a fresh moisture regime (Jameson 1963) and gently rolling topography. The original mixed stand was clear-cut and logged in small blocks. Prior to planting, slash was removed, and part of the humus horizon was scraped off with a bulldozer.

METHODS

The plantations were established in May 1962 at Riding Mountain and in May 1963 at Moodie. Three-year-old stock (3-0 or 2-1) was planted using the slit method. At Moodie, jack pine, red pine, and white spruce were planted, while at Riding Mountain only white spruce was planted. Initial mortality was filled in the following spring.

Seedlings were planted at spacings of 1.2, 1.8, 2.4, and 3.0 m in square plots of 11 x 11 trees (121 trees per plot); thus plot size varied according to spacing. Each spacing was replicated four times for each species at each location.

During the first measurement in 1973, plots with excessive mortality were abandoned (Table 1 indicates missing plots). No plots were abandoned in 1978; therefore, all plots measured in 1973 were remeasured in 1978.

The 1978 measurements included dbh of all living trees whose height had reached 1.37 m (breast height). On each pine plot, about 20 sample trees covering the range of diameters were selected for height and crown width measurement. Crown widths were not measured on plots where excessive branch overlap occurred; i.e., at 1.2- and 1.8-m spacings in jack pine and 1.2-m spacing in red pine. All living spruce trees were measured for height. The condition of each tree was assessed and recorded.

Analysis was based on trees with complete surround; i.e., a tree was included in the analysis only if all four of its immediate neighbors were present and living. All border trees were excluded. Data from trees used in the analysis are summarized in Table 1.

Table 1. Summary statistics of trees with complete surround, 1973 and 1978

Spacing (m)	No. plots	Dbh (mm)							Height (m)							Crown width (m)						
		No. trees	1973 Avg.	1973 Min.	1973 Max.	1978 Avg.	1978 Min.	1978 Max.	No. trees	1973 Avg.	1973 Min.	1973 Max.	1978 Avg.	1978 Min.	1978 Max.	No. trees	1973 Avg.	1973 Min.	1973 Max.	1978 Avg.	1978 Min.	1978 Max.
Jack pine																						
1.2	4	143	35.8	5.1	66.0	59.8	10.2	106.7	42	3.28	2.10	4.48	5.55	4.33	7.53	0						
1.8	2	77	40.5	5.1	78.7	78.6	17.8	137.2	25	3.32	2.13	4.63	5.78	3.81	7.13	0						
2.4	4	172	42.1	10.2	86.4	92.7	33.0	157.5	62	3.17	1.22	4.12	5.56	2.44	7.26	62	2.28	0.55	3.81	3.19	0.61	6.10
3.0	4	192	36.7	5.1	63.5	87.2	27.9	132.1	64	2.93	1.68	4.09	4.67	2.90	6.34	64	2.25	0.98	3.26	3.51	1.62	5.03
Total	14	584	38.6	5.1	86.4	81.0	10.2	157.5	193	3.13	1.22	4.63	5.29	2.44	7.53	126	2.26	0.55	3.81	3.36	0.61	6.10
Red pine																						
1.2	4	155	24.7	7.6	58.4	60.4	22.9	106.7	56	2.14	0.34	3.72	4.07	0.46	5.91	0						
1.8	2	77	24.4	7.6	50.8	77.8	33.0	132.1	36	2.23	0.79	3.11	4.44	1.22	5.82	35	1.22	0.30	1.83	2.22	0.61	3.45
2.4	2	91	33.3	12.7	63.5	98.9	40.6	139.7	41	2.72	1.68	3.63	5.11	3.45	6.34	38	1.62	0.98	2.13	3.01	1.68	3.96
3.0	4	230	31.2	7.6	66.0	96.3	35.6	157.5	77	2.45	0.85	3.41	4.66	2.56	6.10	77	1.60	0.61	2.74	2.76	1.52	4.12
Total	12	553	28.8	7.6	66.0	84.1	22.9	157.5	210	2.38	0.34	4.63	4.55	0.46	6.34	150	1.52	0.30	2.74	2.70	0.61	4.12

White spruce data are not included because of that species' slow growth and lack of spacing effects at the time.

RESULTS

Tree Growth

Basal area increment during 1973-78 showed a strong positive relationship with spacing (Fig. 1). Jack pine grew 165% faster at the widest spacing than at the closest spacing, and red pine grew 106% faster. In 1973, spacing and dbh explained 73% of the variation in basal area increment for jack pine and 82% for red pine, with spacing alone accounting for nearly half of this variation for both species (Table 2). Dbh increment showed a similar trend, although relative differences were smaller.

Red pine had higher basal area increments at all spacings than jack pine during 1973-78. Although in 1973 the average dbh of jack pine was about one-third greater than that of red pine (Bella and De Franceschi 1974), during the last 5-year period red pine caught up to jack pine and at wider spacings surpassed it (Fig. 2).

Height increment was not as strongly affected by spacing as was basal area increment, nor was the effect consistent (Fig. 3). In jack pine, height increment declined with wider spacing, namely, from about 2.5 m at the narrowest spacing to 1.8 m at the 3.0-m spacing. In red pine there was very little difference between spacings, although the highest increment occurred at medium spacing. Spacing alone explained 33% of the variation in height increment for jack pine; height and dbh in 1973 were not significant (Table 3). In red pine the explained variation in height increment increased from 10% with spacing alone to 30% when height was included (Table 3). Red pine height increment depended mainly on tree size (dbh and height) in 1973 and much less on spacing.

Figure 4 shows the relationship between average crown width and spacing for jack pine and red pine in 1973 and 1978. The data came from trees with crown measurements in 1973 and 1978. Crowns were not measured where excessive branch overlap precluded reliable measurement. As Figure 4 indicates, there was full or nearly full crown closure at all spacings for both pines, with the exception of red pine at the widest spacing. Jack pine had wider crowns than red pine, although this difference now is diminishing following crown closure.

Although white spruce had not reached tree sizes large enough to show spacing effects, it is worth noting that average total height in 1978 was 1.75 m at Moodie and 2.39 m at Riding Mountain. This is less than half of the average height of either pine at Moodie.

Stand Growth

To provide an approximate measure of stand productivity in terms of stem wood, stand basal area and basal area increment values per hectare are presented. These were estimated from average dbh from each plot and are expressed per hectare based on spacing distance, assuming a full complement of trees (Table 4). Figure 5 shows basal area increment for 1973-78 over initial basal area per hectare in 1973. In general, closer spacings—with higher initial basal area—had higher increments in the current period. Although red pine had somewhat lower initial basal areas than jack pine, it had greater current increments than jack pine at similar initial basal areas.

To define actual mortality trends, mortality was plotted for different spacings for the two pines by two initial (1973) tree size classes as a percentage of the number of living trees with complete surround in 1973 (Fig. 6). Mortality between 1973 and 1978 was generally low—on the average under 5% for either species—and, as expected, somewhat higher for narrow than for wide spacings. Red pine at 1.2-m spacing had exceptionally high (nearly 16%) mortality mainly among larger trees, which seemed to have been caused by porcupines.

Photos in Figure 7 illustrate tree form in these plantations at different spacings 15

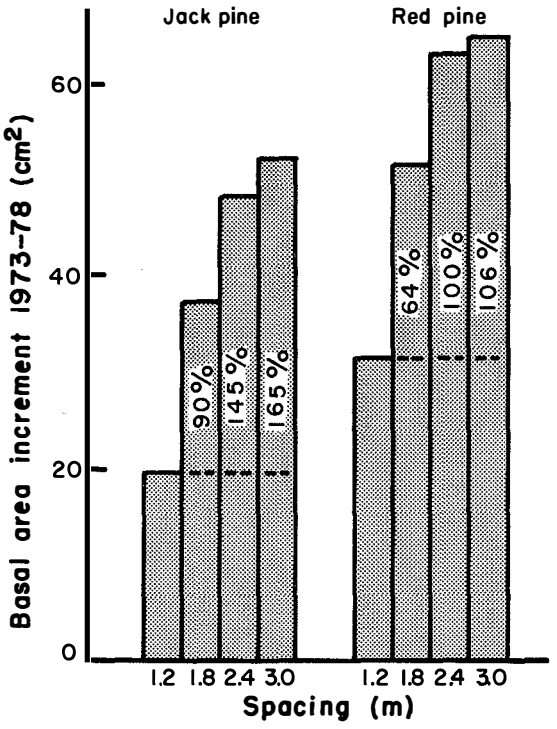


Figure 1. Basal area increment of the tree of average dbh in 1973 by spacing (estimated from regressions in Table 2).

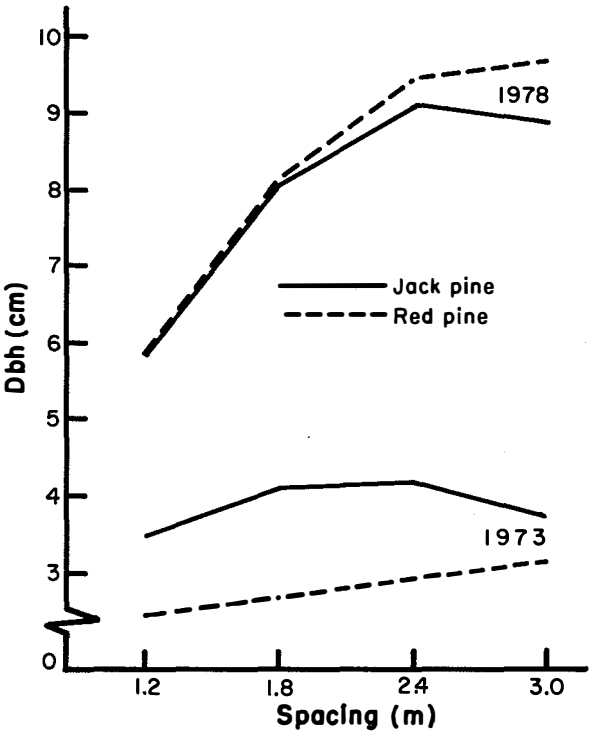


Figure 2. Dbh over spacing relationship for jack pine and red pine in 1973 and in 1978 (from regressions in Table 2).

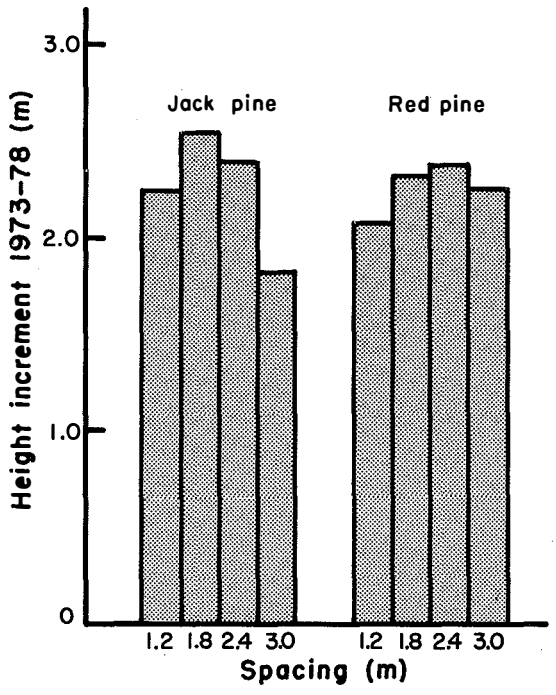


Figure 3. Height increment 1973-78 over spacing (values estimated from regressions in Table 3).

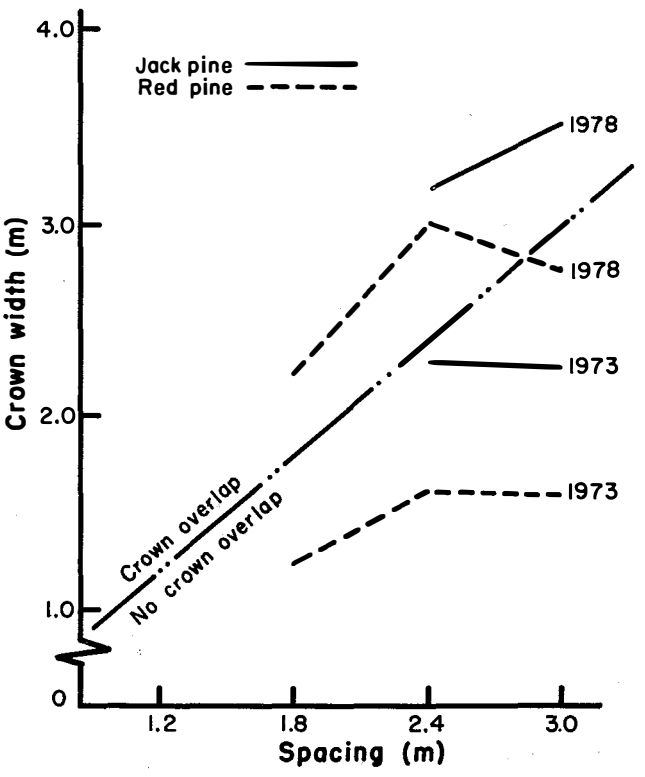


Figure 4. Average crown width at different spacing for trees measured in 1973 and 1978.

Table 2. Regressions of diameter increment, basal area increment, and dbh (1973 and 1978) over spacing and dbh in 1973

Dependent variable	Species	Independent variables X_1 = spacing (m); $X_2 = X_1^2$; X_3 = dbh in 1973 (mm); $X_4 = X_3^2$ — Regression coefficients† a	b_1	b_2	b_3	b_4	R^2	N
Diameter increment 1973-78 (mm)	Jack pine	-36.1613	49.6131	-8.16324	0.31732		0.640	584
		-33.5511	59.5291	-10.4408			0.548	584
	Red pine	-45.5762	62.6253	-11.3913	1.13405	-0.00854909	0.723	553
		-30.9748	69.7030	-12.5137			0.546	553
Basal area increment 1973-78 (mm^2)	Jack pine	-6755.63	5803.72	-951.363	58.7312	0.587357	0.731	584
		-6916.24	9360.65	-1772.84			0.334	584
	Red pine	-8709.09	7164.49	-1262.49	175.265		0.817	553
		-6412.30	9101.89	-1548.70			0.369	553
Dbh in 1973 (mm)	Jack pine	8.22562	31.2489	-7.17740			0.032	584
	Red pine	19.6952	4.01767				0.060	553
Dbh in 1978 (mm)	Jack pine	-25.3255	90.7780	-17.6182			0.264	584
	Red pine	-17.8701	80.7571	-14.1467			0.356	553

† All regression coefficients were significant at the 0.01 level.

Table 3. Regressions of 1973-78 height increments (in m) over spacing, 1973 dbh, and 1973 height

Species	Independent variables X_1 = spacing (m); $X_2 = X_1^2$ — Regression coefficients† a	b_1	b_2	b_3	b_4	R^2	N
			X_3 = dbh (mm) in 1973; X_4 = height (m) in 1973				
Jack pine	0.534	2.10136	-0.559490	-0.00616365	-0.0652962	0.342	192
	0.301	2.35108	-0.615129			0.330	192
	1.862			0.00819098		0.053	192
	1.513				0.206590	0.050	192
			X_3 = height (m) in 1973; $X_4 = X_3^2$				
Red pine	-1.061	0.908761	-0.200998	1.70016	-0.287064	0.302	197
	0.993	1.21691	-0.266935			0.103	197
	-0.227			1.73256	-0.286525	0.249	197

† Coefficients not significant at 0.05 level of probability are underlined. All coefficients in other regressions in this table are significant at the 0.01 level.

Table 4. Estimates of stand basal area and increment for fully stocked stands

Species	Spacing (m)	Trees·ha^{-1} †	Plot no.	Avg. dbh (mm)†† 1973	Avg. dbh (mm)†† 1978	Basal area of a fully stocked stand (m^2·ha^{-1}) 1973	Basal area of a fully stocked stand (m^2·ha^{-1}) 1978	Basal area of a fully stocked stand (m^2·ha^{-1}) Increment
Jack pine	1.2	6944	1	38.0	61.6	7.875	20.695	12.820
			2	31.6	60.0	5.446	19.634	14.188
			3	31.9	55.7	5.550	16.920	11.370
			4	40.6	62.9	8.990	21.578	12.588
	1.8	3086	5	44.8	82.6	4.865	16.537	11.672
			6	36.2	74.4	3.176	13.416	10.240
	2.4	1736	9	41.0	88.0	2.292	10.559	8.267
			10	41.5	95.9	2.348	12.539	10.191
			11	46.5	98.7	2.948	13.282	10.334
			12	37.6	84.9	1.928	9.828	7.900
	3.0	1111	13	33.8	86.8	0.997	6.574	5.577
			14	40.1	90.1	1.403	7.084	5.681
			15	39.7	90.4	1.375	7.131	5.756
			16	32.1	80.6	0.899	5.669	4.770
Red pine	1.2	6944	1	32.6	67.2	5.796	24.629	18.833
			2	27.4	62.8	4.094	21.509	17.415
			3	18.5	55.7	1.867	16.920	15.053
			4	26.3	60.9	3.772	20.227	16.455
	1.8	3086	7	23.0	76.2	1.282	14.073	12.791
			8	25.3	78.8	1.551	15.050	13.499
	2.4	1736	10	34.1	95.6	1.585	12.461	10.876
			12	32.5	102.0	1.440	14.185	12.745
	3.0	1111	13	29.7	91.6	0.770	7.321	6.551
			14	23.6	81.1	0.486	5.739	5.253
			15	33.9	101.1	1.003	8.919	7.916
			16	37.4	110.9	1.220	10.732	9.512

† Trees per hectare, assumming full stocking at a given spacing.

†† From Table 1.

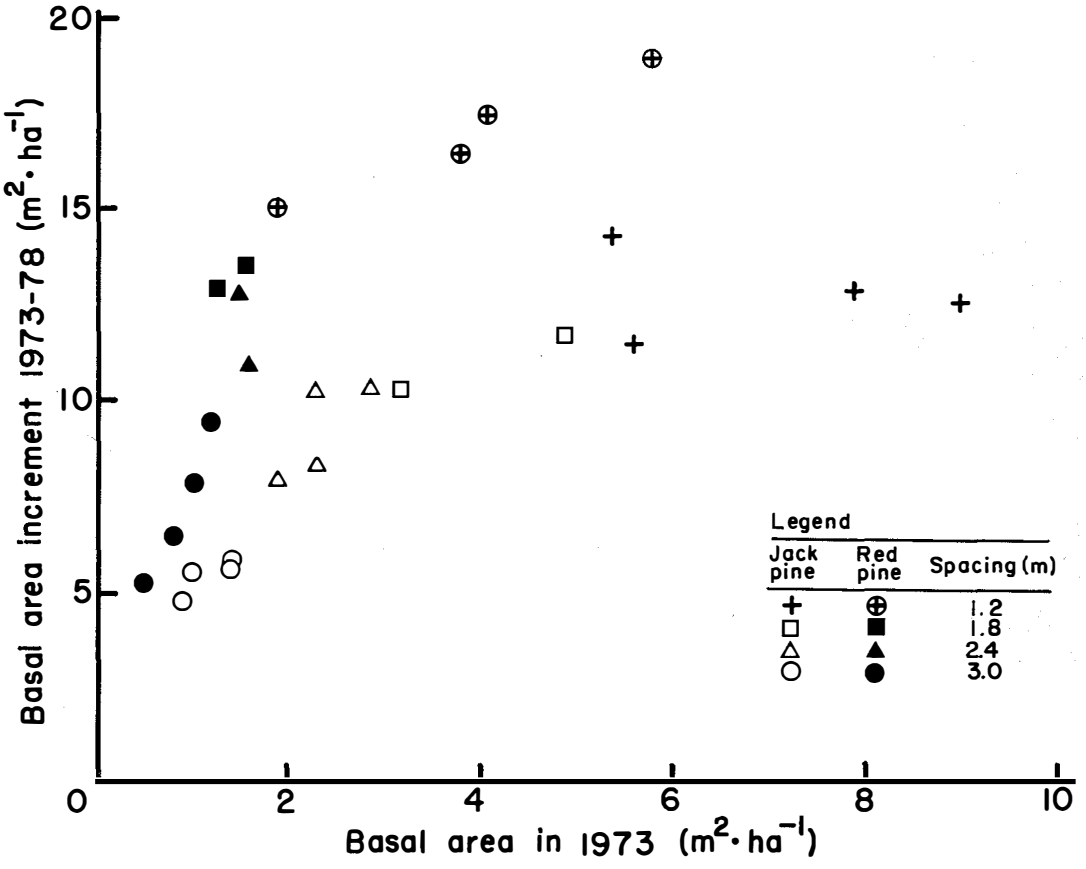


Figure 5. Stand basal area increment over initial density.

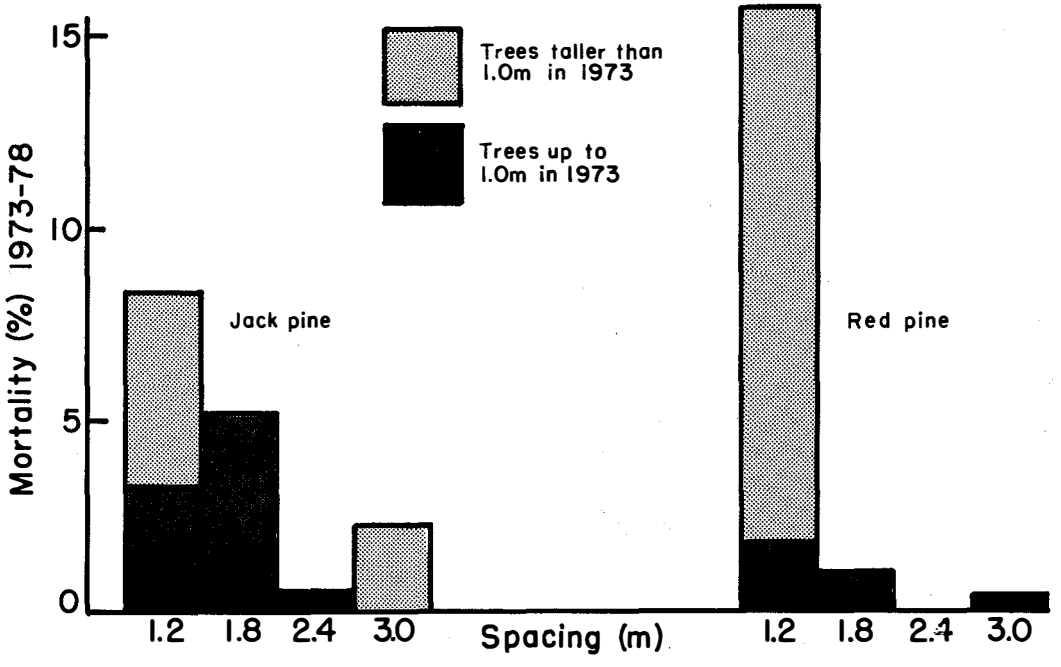
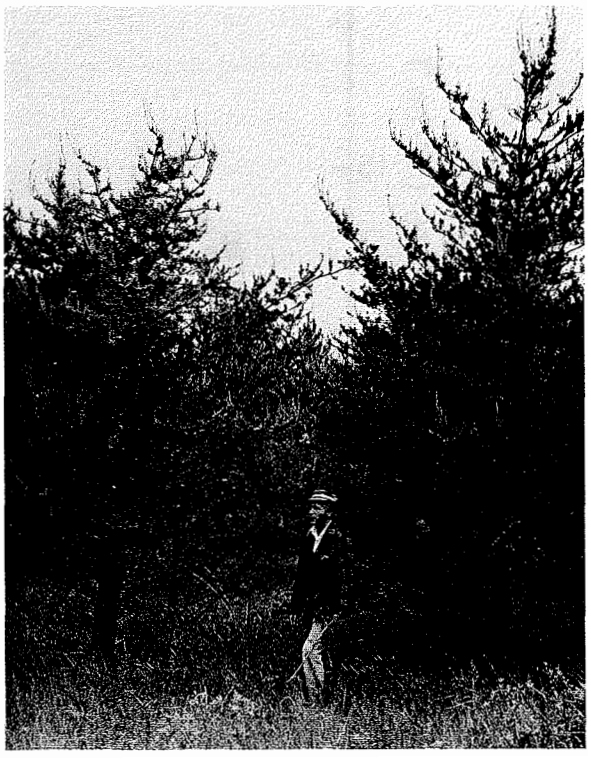
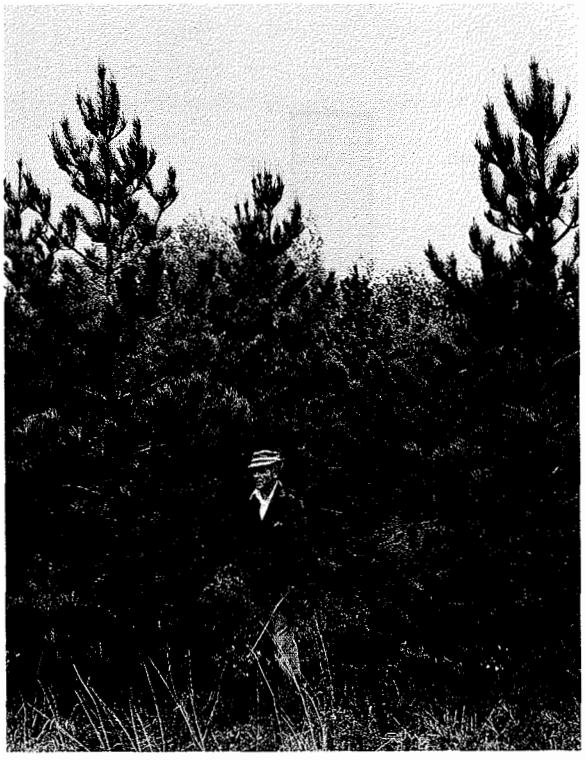


Figure 6. Percentage mortality 1973-78 by two initial tree size classes for jack pine and red pine.

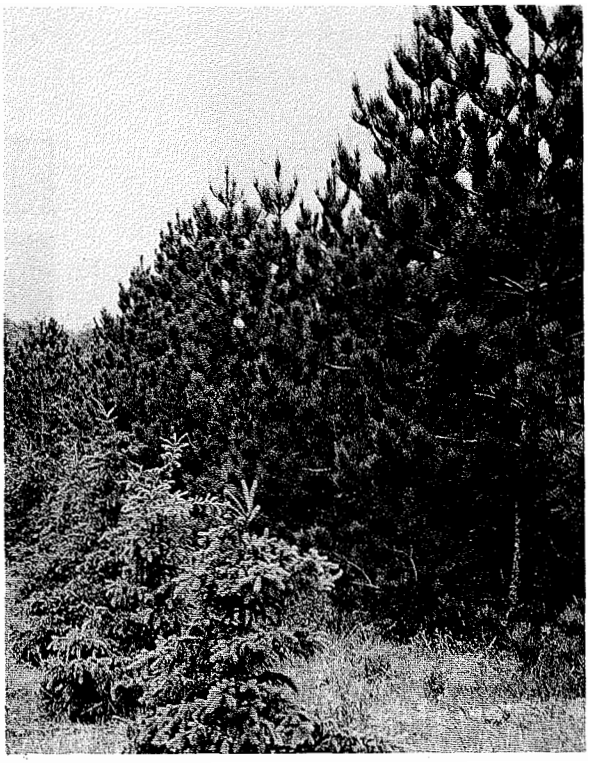
a. Jack pine at 1.2-m spacing has full crown closure and fairly good stem form; lack of self-pruning may be caused by edge effect.



b. Jack pine at 3.0-m spacing shows poor tree form, lack of strong leader growth, and heavy branches to ground.



c. Red pine at 3.0-m spacing has good form and height growth as well as full crowns.



d. White spruce vs. red pine.

Figure 7. Jack pine, red pine, and white spruce at Moodie, Manitoba, 15 years after planting.

years after planting. At wide spacing (i.e., 3 m), jack pine had heavy branches, irregular crowns, and multiple leaders (Fig. 7b). Although this condition in part may relate to seed source, most of it is probably the result of open stand conditions. In red pine, open spacing does not seem to result in any undesirable effects on tree form, aside from full crowns to ground level.

DISCUSSION AND CONCLUSIONS

These results show increasing tree growth in basal area (i.e., in dbh) with wider spacing; the difference between the closest and widest spacings exceeded 100%. Trees at the two widest spacings still were growing at or near their maximum potential, especially red pine, which did not even reach crown closure at 3.0-m spacing. In close spacings, there already has been a substantial reduction in increment during the last 5 years due to crowding.

As a result of these differences in diameter increment between various spacings, substantial differences in average diameter were evident between trees growing at the narrowest and the two widest spacings. At these wide spacings, red pine surpassed jack pine by a slight amount.

In terms of height growth, the two pines responded differently to spacing density. Jack pine height growth was reduced with increased spacing; instead, most of the growth seemed to go into heavy branches, with a consequent deterioration in tree form. At the same time, red pine height growth was affected little by spacing.

Although tree growth information provides an indication of spacing effects, it is the stand production values per unit area that are of most interest. Using basal area per hectare as a measure of stem wood productivity, production as well as increment were greatest at the closest spacing, although the next closest spacing (1.8 m) was not far behind (Fig. 5). Rapid growth is expected to be maintained much longer at intermediate spacings, for which production likely soon will reach or even surpass that of the closest spacings. At the widest spacings there was considerable loss in stem wood production, but this is expected to be reduced or even eliminated with continued rapid growth over the years. Following initially slower growth, red pine by 1978 was outproducing jack pine at all spacings.

Regular or suppression mortality usually commences after crown closure, although trees may die from other causes throughout the stand's life. In order to distinguish between causes, dead trees were separated into two size classes. Trees in the under 1-m size class—smaller because of possible planting defects, browsing, or related early damage—were crowded out first; those in the over 1-m class were likely to be dying from current causes such as porcupine damage and insect and/or disease attacks. During 1973-78 mortality was generally low, although it was somewhat higher for narrow than for wide spacings for both pine species. The only substantial mortality occurred in red pine at 1.2-m spacing, where on one plot nearly half of the trees died from what appeared to be porcupine damage. With increased crowding, especially at closer spacings, there likely will be an acceleration in mortality over the coming years.

Tree form and branchiness are important factors in timber utilization. The poor form, multiple leaders, and heavy branches that developed in jack pine at wide spacing preclude the production of better quality sawlog material, although the trees may be suitable for other uses. In contrast, red pine at this time showed no undesirable characteristics that could be related to open spacing, aside from developing full crowns to ground level. These full crowns, however, likely will ensure vigorous growth even after crown closure and overlap.

This characteristic of red pine to retain regular tree form even at wide spacings has important implications for its management. Planting at wide spacing generally means lower establishment cost as well as a reduction in or elimination of the need for thinning. By concentrating volume on fewer but larger trees, logging cost is reduced, and there may be an increase in merchantable

yield. On the other hand, loss of trees through mortality at wide spacings can mean gaps in the stand, incomplete utilization of the site, and a reduction in yield.

White spruce is known to have relatively slow juvenile growth. In this study, the average height of spruce 16 growing seasons after planting was less than half that of the two pines. Although spruce growth accelerated in 1973-78, it is doubtful that it will catch up to pine. Final assessment of the relative performances of these species must wait until the plantations are near rotation age.

In brief, the following conclusions were reached:

1. Jack pine should be planted at spacings between 2 and 2.5 m if reasonably good tree form is an objective.

2. Red pine generally retains good tree form and can be planted at any spacing to fulfill particular management objectives.

3. Although in the first decade jack pine outgrew red pine, in the following 5-year period red pine more or less caught up to or even surpassed jack pine.

4. For planting on average sites in southeastern Manitoba, red pine should be favored over jack pine, while spruce should be considered only as a poor third choice.

Spacing studies commonly monitor stand development until or near rotation age. Because this study's results cover only the first 15 years of stand growth, possibly one-quarter of rotation, the above conclusions will have to be verified and expanded when further remeasurement data become available.

REFERENCES

Bella, I.E. and J.P. De Franceschi. 1974. Early results of spacing studies of three indigenous conifers in Manitoba. Environ. Can., Can. For. Serv., North. For. Res. Cent. Edmonton, Alberta. Inf. Rep. NOR-X-113.

Jameson, J.S. 1963. Comparison of tree growth on two sites in the Riding Mountain forest experimental area. Can. Dep. For. Publ. No. 1019.

Mueller-Dombois, D. 1964. Forest habitat types of southeastern Manitoba and their application to forest management. Can. J. Bot. 42: 1417-1444.

Rowe, J.S. 1972. Forest regions of Canada. Dep. Fish. Environ. Can., Can. For. Serv. Publ. No. 1300.