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**PLANTING OF CONIFERS IN THE
SPRUCE WOODS FOREST RESERVE, MANITOBA
1904-1929**

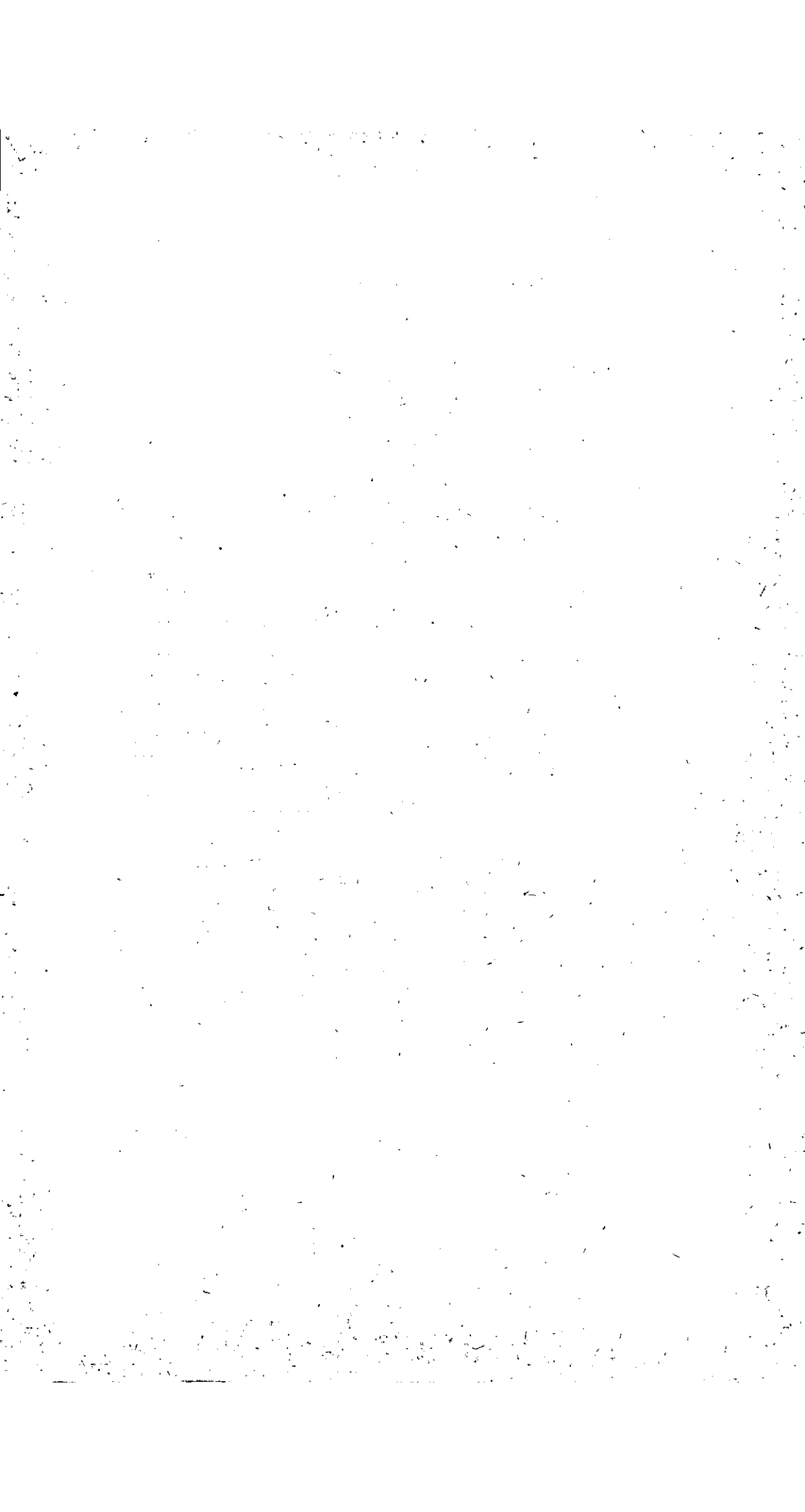
by
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PLANTING OF CONIFERS IN THE SPRUCE WOODS FOREST RESERVE, MANITOBA 1904-1929

Project M. S. 113

by

J. S. JAMESON*

INTRODUCTION

From 1904 to 1929, considerable planting of conifers was undertaken by the Forestry Branch in the Spruce Woods Forest Reserve in Manitoba. Five species were planted: jack pine (*Pinus Banksiana* Lamb.), lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Englemann), Scots pine (*Pinus sylvestris* L.), white spruce (*Picea glauca* (Moench) Voss), and Norway spruce (*Picea abies* Dietr.)**. The purpose was to study the survival, causes of mortality, and rate of growth of these species when set out under different planting conditions. There was, however, no over-all planting plan. As a result, although records were kept of most plantations, data were gathered inadequately and at irregular periods. Consequently, investigation of the different experimental methods was not made and plantings were often duplicated.

Plantations set out prior to 1927 were purely experimental in nature; those established in 1927 and 1928 were for reforestation purposes. This report is concerned only with the former.

DESCRIPTION OF PLANTING AREA

Location, Geology and Topography

The Spruce Woods Forest Reserve, about 200 square miles in area, is located in the south-central section of Manitoba. It is described by Halliday (9) as a relict area of the Boreal Forest, representing the southeastern extension of the Mixedwood Forest Section, B. 18 (Figure 1).

The reserve occupies the sandy and gravelly deposits of the old Assiniboine delta, formed where the river emptied into Lake Agassiz in post-glacial times. These deposits extend between Portage la Prairie, Plumas, Neepawa, Brandon and the Tiger Hills (Figure 1). In the vicinity of Brandon the material is of a coarse gravelly texture; eastward it grades into coarse, medium, fine, and silty sands. In the central portion of the delta, i.e., south and west of Carberry, the sandy materials have been blown into dunes, and dune topography characterizes the largest portion of the reserve. Most of the plantations examined, however, were set out on level topography, although a few near Camp Shilo were established on the old dunes.

The plantations are located in two areas: one east of Camp Shilo, in Sec. 7, Twp. 10, Rge. 16, W.P.M.; the other and larger, southeast of old Camp Hughes, in Sec. 24, Twp. 10, Rge. 16, W.P.M., and Sec. 19, Twp. 10, Rge. 15, W.P.M.

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**Nomenclature follows Gray's Manual of Botany, 8th edition.

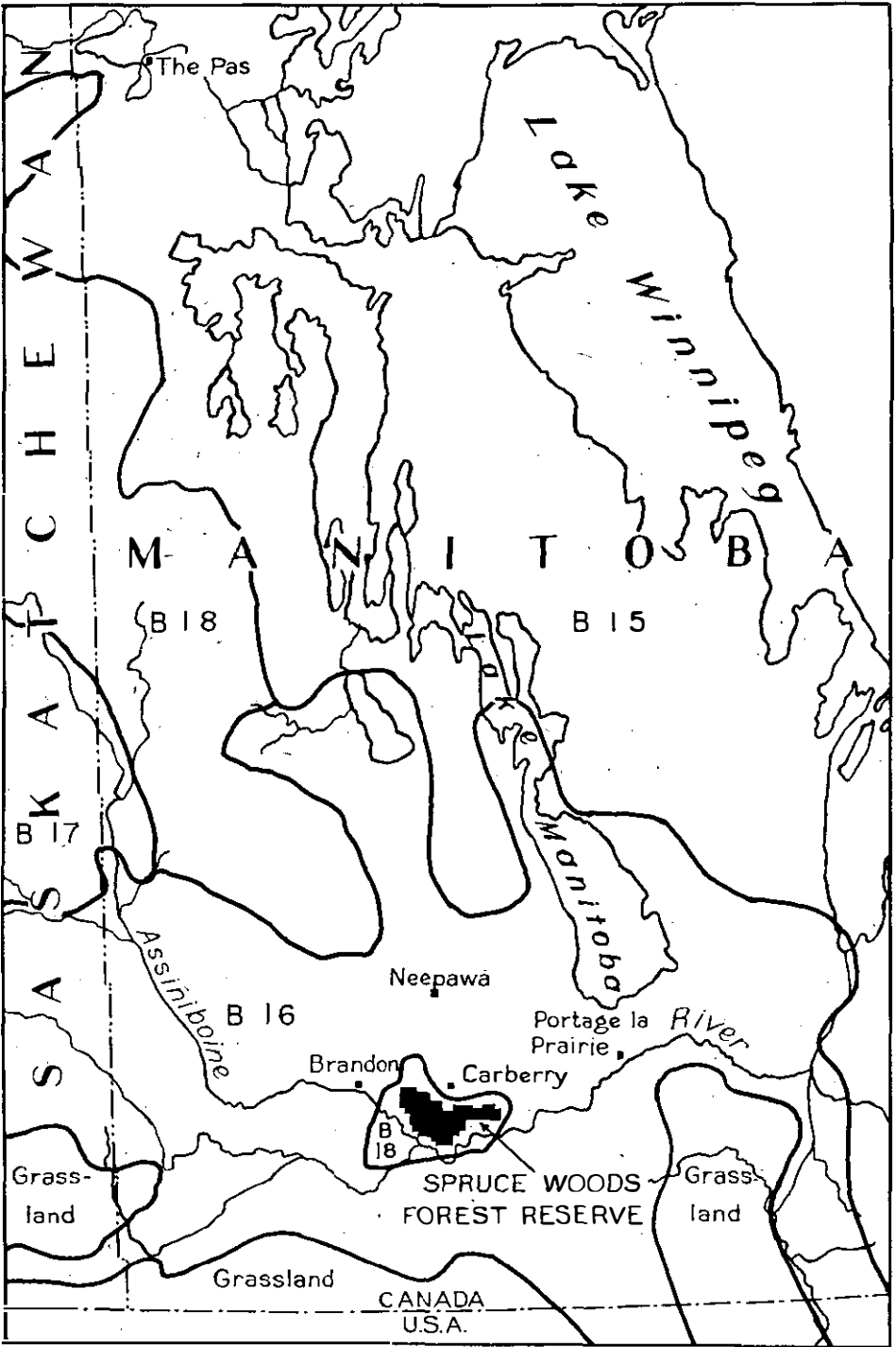


FIGURE 1.—Location of forest sections and the Spruce Woods Forest Reserve.

Climate

The climate, typical of southwestern Manitoba and southeastern Saskatchewan, is characterized by cold dry winters and hot summers. The average annual precipitation (rain and snow) is low, and is distributed mainly throughout the summer months when the rate of evaporation is high. Halliday (9), using Thornwaite's method, indicates that moisture is deficient at all seasons. Although precipitation in May, the usual month of planting, is normally 1.62 inches, the probability of drought occurring is two in seven.

The following meteorological data (5) are based on 29 years of weather records taken at Brandon, a few miles west of the reserve:

Mean January temperature.....	-3° F.
Mean July temperature.....	65° F.
Average length growing season.....	120 days
Average annual precipitation.....	15.73 inches (including snow)
Average annual snowfall.....	37.0 inches

Vegetation

The predominant natural vegetation on the dry upland sites consists of scattered clumps of white spruce and a dense cover of prairie grasses (Figure 2). A few herbaceous species are also present. In the spruce clumps the typical ground vegetation is a dense mat of *Dicranum* and *Thuidium* mosses. In the plantations where tree survival is high, most of the prairie grasses have disappeared, herbaceous vegetation is lacking, and the sandy soil is covered with a deep needle litter; where mortality has been high and crown canopy is open, a thick cover of grasses remains.

The most common species observed in the prairies and open plantations were:

Grasses: *Festuca scabrella*, *Poa palustris*, *Bromus ciliatus*, *Stipa comata*, *Oryzopsis asperifolia*.

Herbs: *Artemisia frigida*, *Lithospermum canescens*, *Achillea Millefolium*, *Anemone patens*, *Comandra pallida*, *Galium boreale*, *Agastache Foeniculum*, *Viola adunca*.

Shrubs: *Juniperus horizontalis* occurring in dense patches; scattered specimens of *Rosa* spp., *Prunus* spp., and *Betula glandulosa*.

Aspen (*Populus tremuloides*) and bur oak (*Quercus macrocarpa*) are common on moister sites, while larch (*Larix laricina*) and black spruce (*Picea mariana*) are found on the swamp sites. Strangely enough, jack pine does not occur naturally.

In an earlier report (12) white spruce was said to have covered much of the area when the Canadian Pacific Railway was built through the west in the 1860's, at which time the timber was removed for construction purposes. Subsequently, the area was reported to have been repeatedly and severely burned, thus reducing the forest to its present limited area. Bird (3,4) was of the opinion that the valleys and north slopes had been fairly heavily forested, but that frequent fires, started by the Indians in the adjacent prairies, had killed many of the trees and kept the forest from advancing. There is, however, very little evidence in the soil profiles of such extensive former forest cover.

Soils and Site

The chief soil association of the area was identified from numerous pits as a Black-earth type, indicating that past vegetation was primarily grass. The typical soil profile in the plantations is as follows:

- $\frac{1}{2}$ -inch needle litter,
- O₁—Up to $\frac{1}{2}$ -inch partly decomposed needles and grass, usually black in colour,
- A₁—9 to 11 inches grey-black to very dark brown (10YR2/2)* (pH = 7.0) somewhat compacted loamy sand, with particles of silica sand interspersed throughout, giving a salt-and-pepper effect. The A₁ horizon grades to a poorly developed
- B—of about 5 inches, dark brown in colour (10YR4/3) (pH = 7.2) also somewhat compacted loamy sand, which grades almost imperceptibly to the
- C—horizon, a light brown (10YR5/8) (pH = 7.4) medium to coarse stone-free structureless sand.

This type of profile is also common to the spruce clumps and to the sandy grassland areas, although in the latter the A₁ is usually slightly darker and more loamy. However, there is very little variation between the profiles on the gentle slopes, the tops of the knolls, or the level areas between.

Within some of the spruce clumps there is evidence of podzolization, where a grey A₂ horizon, varying in depth from 0 to $\frac{1}{2}$ -inch with a decidedly acid pH (5.2), has formed in the old A₁ horizon. It represents, therefore, only recent podzolization or degradation. Within one or two plantations there was a similar development of an A₂ horizon, although it was very shallow, never continuous nor of any great extent.

There are some minor variations in the soils, the parent materials ranging from a fine to a coarse sand, either completely stone-free or only very slightly stony (3 to 5 per cent total volume). The stones of the coarse skeleton are less than three inches in diameter. Using Hills' (10) method of site classification, the sites may be identified as 0:0 or 0:1, the first digit referring to the moisture regime and the second to the pore pattern. In this case, the moisture regime is classed as very dry, while the pore pattern is classed as very open, coarse, structureless sand, or open, fine to medium sand.

SUMMARY OF PLANTING

Sixty-two experimental plantations, totalling 204.5 acres, were set out during the period 1904 to 1926. In 1952, only 33 plantations, totalling 115.5 acres, still existed. Table 1 lists, by years, the species and acreage planted from 1904 to 1929, and Table 2 describes each experimental plantation under the following headings:

1. Plantation number
2. Species
3. Age of stock
4. Area planted
5. Planting area
6. Per cent mortality one year after planting
7. Per cent mortality by 1952.

*Munsell Colour Chart.

TABLE 1.—PLANTINGS
 SPRUCE WOODS FOREST RESERVE, 1904-1929

Year	Total Number of Trees Planted												
	Area (Acres)	Scots Pine		Jack Pine		Lodgepole Pine		Caragana		White Spruce		Norway Spruce	
		Original	Refills	Original	Refills	Original	Refills	Original	Refills	Original	Refills	Original	Refills
1904	3.50	9,500											
1905	4.37	13,000											
1906	6.44	17,000											
1907	9.53	29,000											
1908			10,100										
1913	0.20			480		600							
1916	27.88	45,900		17,010		10,260		2,025					
1917	36.75		2,800	1,500	2,900	2,050				95,850		1,900	
1918	37.00			67,500	6,885					20,700	45,300		
1919					30,790						47,925		400
1920	10.25	30,000								529	4,050		
1921	16.00			43,200	1,300						5,000		
1922	3.56	6,961			1,346					1,429			
1924	2.12	715			6,011								
1925	39.04	80,893			11,970		2,752						
1926	7.87	20,996											
1927	20.00	22,400			15,100		11,600						
1928	1.60				4,320								
1929													
	226.11	276,365	12,900	168,437	41,875	25,213	2,050	2,025		127,508	106,275	1,900	400

Total all species (original)—601,448.

Total all species (refills)—163,500.

TABLE 2.—SUMMARY OF PLANTATIONS

Plantation No.	Species	Age of Stock	Area in Acres	Planting Area.	Approx. Per cent Mortality 1 year after Planting	Per cent Mortality 1952
1-04	Scots pine	1-0	3.50	Grass.....	100	100
		2-0			55	100
2-05	"	2-0	4.37	Furrows.....	15	82
3-06	"	2-0	6.44	"	20	85
4-07	"	2-0	9.53	"	35	92
5-13	Jack pine	3-0	0.10	Transplant bed.....	0	60
6-13	Lodgepole pine	3-0	0.10	Transplant bed.....	0	51
7-16	Jack pine	3-3	3.75	Furrows.....	10	39
8-16	Scots pine	3-0	10.00	"	5	77
9-16	Lodgepole pine	3-3	3.80	"	20	57
10-16	Jack pine	3-3	1.53	"	10	65
	Caragana	4-0		"	55	100
11-16	Jack pine	4-0	1.80	Furrows.....	10	86
12-16	Scots pine	3-0	7.00	"	5	53
13-17	White spruce	3-0	10.00	"	50	100
14-17	Jack pine	3-0	0.50	"	40	100
	Norway spruce	3-0	0.75	"	70	100
15-17	White spruce	3-0	3.75	"	50	100
16-17	White spruce	3-0	10.00	Furrows	50	100
17-17	"	3-0	10.00	"	50	100
18-17	"	3-0	1.75	"	50	100
20-18	Jack pine	3-0	10.00	"	60	87
21-18	Jack pine	3-0	13.00	"	60	100
	White spruce	4-0		"	40	100
22-18	Jack pine	2-0	4.00	Furrows.....	60	95
23-18	"	3-0	10.00	"	60	100
	White spruce	3-0		"		
		4-0		"	40	100
26-20	Scots pine	3-0, 2-0	10.00	"	50	87
27-20	White spruce	3-0	0.25	Poplar.....	10	100
34-21	Jack pine	?	10.00	Grass and Poplar.....	99	100
35-21	Jack pine	?	6.00	Grass and Poplar.....	99	100
40-22	Scots pine	?	0.50	Grass.....	25	100
41-22	"	?	0.50	Poplar.....	25	100
42-22	"	?	0.25	Poplar.....	20	100
43-22	White spruce	?	0.25	Ground Cedar.....	55	100
44-22	Scots pine	?	0.25	Poplar.....	20	100
45-22	"	?	0.25	Ground Cedar.....	20	59
46-22	Jack pine	?	0.25	Poplar.....	30	100
47-22	"	?	0.25	Ground Cedar.....	65	72
48-22	White spruce	?	0.25	Poplar.....	30	100
50-22	Scots pine	?	0.06	Grass.....	90	100
51-22	White spruce	?	0.05	Grass.....	95	100
52-22	Scots pine	?	0.40	Poplar.....	70	100
53-22	"	?	0.30	Ground Cedar and Poplar	60	100
56-24	Jack pine	?	0.67	Furrows.....	10	26
57-24	Jack pine	?	0.67	Furrows.....	10	43
58-24	"	?	0.33	Burned Grass.....	25	52
59-24	"	?	0.04	Grass.....	10	100
60-24	"	?	0.21	"	10	100
61-24	Scots pine	?	0.21	"	25	61
62-24	Scots pine	?	0.10	Ground Cedar.....	20	73
63-24	Jack pine	?	0.10	"	20	21
64-24	Scots pine	?	0.07	Burned Grass.....	25	100
65-24	Jack pine	?	0.13	Grass.....	30	100
79-25	Scots pine	2-0	3.50	Furrows.....	20	87
80-25	Scots pine	2-0	6.50	Furrows.....	20	91
81-25	"	2-0	12.00	"	20	89

TABLE 2.—SUMMARY OF PLANTATIONS—*Concluded*.

Plantation No.	Species	Age of Stock	Area in Acres	Planting Area	Approx. Per cent Mortality 1 year after Planting	Per cent Mortality 1952
82-25	Lodgepole pine	{2-0 2-2	1.00	Furrows.....	30	89
83-25	Scots pine	2-2	1.33	"	15	88
84-25	"	2-0	4.17	"	20	75
85-25	Jack pine	{2-0 2-2	4.00	"	20	72
86-25	Scots pine	2-0	1.00	Furrows.....	25	92
87-25-1	"	?	5.50	"	?	<100
87-25-2	"	2-2	0.04	"	25	52
97-26	"	2-0	5.11	"	25	100
98-26	"	2-0	1.11	"	25	100
99-26	"	2-0	1.65	"	25	97

Note: The last figure in the plantation number refers to the year planted, e.g., 99-26, Plantation No. 99, planted in 1926.

Most of the stock was obtained from a nursery operated by the Department of Agriculture at Indian Head, Saskatchewan, although some was obtained from a Forestry Branch nursery at Shilo, Manitoba. The nurseries had acquired jack pine and white spruce seed locally; Scots pine seed from Central Sweden, Finland, Germany, Scotland, and other localities not recorded; lodgepole pine seed from Nicola, British Columbia, and also from sources unknown. The age of the planting stock varied considerably and in some cases is not known. Different-aged stock was usually not planted in the same year; therefore, it is not possible to definitely relate mortality to the age of the stock.

With the exception of three mixed plantations, all were established as pure stands. The mixtures consisted of jack pine and white spruce or caragana in alternate rows; in one other plantation, Norway spruce was planted on one half and jack pine on the other half of the area.

While planting methods varied somewhat, trees were mainly planted with a spade or planting iron in furrows, ploughed in an east-west direction. In a few cases seedlings were set out without ground preparation in young open poplar stands, in open grassland, and in ground-cedar patches. The spacing of the seedlings varied between 3 feet by 3 feet and 4 feet by 4 feet. All plantings were made in the spring of each year.

Method of Sampling Plantations and Compilation

In the summer of 1952, thirty-three plantations were relocated and sampled by C. L. Kirby. They represent, for the most part, those that were considered promising by Tunstall (13) in 1927, and which he recommended for re-measurement.

On plantations one acre in size or less, all trees were tallied by one-inch diameter classes. On those larger than one acre, rows were selected at random to give a sampling area of approximately one acre, and the diameters were tallied of all trees on each selected row. Stump diameters of trees removed in the thinning operation on certain plantations in 1947 were also measured. In each plantation the diameters of 5 to 10 trees in each diameter class were measured to the nearest one-tenth inch, heights to the nearest foot, and the crown classes recorded.

From the height/diameter curves drawn for each plantation, local volume tables were prepared by interpolation from Form-Class Volume Tables (7). The volumes for jack pine and lodgepole pine were obtained from Jack Pine Table 28, Form-Class 65. In the absence of Scots pine volume tables, Red Pine Table 67, Form-Class 70 was used.

Tables have been prepared for each tree species, showing on a per acre basis the survival and growth for each plantation (Tables 3, 4 and 5).

RESULTS

Mortality

Mortality of all species one year after planting varied considerably. Although method of planting, age of stock, and seed provenance undoubtedly were influential, climatic conditions immediately following planting were the most important factors.

By 1952, two mixed plantations (jack pine and white spruce) as well as all pure white spruce plantations, and all pure Norway spruce plantations, were complete failures. Mortality was less severe among the Scots and jack pine, although some plantations of these species were also complete failures. Considering only the 33 plantations remaining in 1952, mortality averaged about 80 per cent (53% to 97%) in Scots pine, 65 per cent (51% to 89%) in the lodgepole pine, and 60 per cent (21% to 95%) in the jack pine.

Causes of Mortality

(a) *Climatic*

In the prairies, summer drought occurs more often than in the forested areas of eastern Canada, and extremely high summer temperatures are common. Consequently, a combination of these two factors has been the most important cause of mortality, particularly in the first few years immediately following planting. Mortality in older plantations was usually light in subsequent years of drought. Inasmuch as the upper layers of these light sandy soils dry rapidly, young plants having a poorly developed root system are easily subjected to drought conditions. The older trees, having a better-developed root system, are much less affected. It is evident, too, that initial mortality during droughty years was lower in the plantations established under poplar or in ground-cedar patches.

White spruce seems to be more susceptible to drought than the other species, and even where it was underplanted the seedlings died. Norway spruce appears to be the next most susceptible, although an insufficient number of plantings was made to establish this fact definitely. These two species, however, are shallow-rooted, and thus would likely be more affected than the deeper-rooted pines. Losses due to drought were considerable in some pine plantations, but on the average were less than for the spruce.

"Winter-kill" (i.e., winter drying) has had a serious effect on Scots pine, damaging older trees in particular. In the winter of 1919-20, unusually deep snows buried the small trees in the more recent plantations and prevented winter-kill. At the same time, in the 1905 to 1907 plantations, where the taller trees projected above the snow line, 20 per cent were killed, while 50 per cent of the remainder suffered severe damage to leaders. Although Norway and white spruce mortality was caused largely by drought and heat, considerable losses from winter-kill occurred in 1917-18 and 1919-20. Lodgepole pine plantations, however, were only slightly damaged, and jack pine was uninjured.

Snow drifting on the north and west sides of young Scots pine plantations caused breakage of branches and leaders. As a result, most of the surviving trees, particularly in plantations of Scottish and Finnish origin, have very poor form. Damage of this type was much less in the jack pine stands, possibly because the species is hardier, and the wood is denser with a higher bending strength.

(b) Biotic

Planting of jack pine and Scots pine under poplar appears to be successful in so far as resistance to drought is concerned. However, this type of stand affords protection to the snowshoe rabbit (*Lepus americanus phaeotus*) which at times becomes very destructive. In 1925-26, for example, all seedlings planted in 1921 and 1922 under poplar or adjacent to the poplar stands were browsed by rabbits and subsequently died. Losses from a similar cause were also reported at that time in Saskatchewan and the Lake States (11, 2).

Additional light mortality was attributed to the pocket gopher (*Thomomys talpoides*), a burrowing animal whose mounds of soil are seen throughout the area. Death of some Scots pine seedlings was caused not only by burying in the mounds, but also by undermining and exposing their roots.

Plantations established in ground-cedar were superior to those planted either in unploughed areas or where the grass was previously removed by burning. In the latter locations, the grass soon recovered sufficiently to compete with the seedlings and mortality was 5 to 10 per cent greater than in the ground-cedar patches. It is probable that grass is more effective in reducing soil moisture than is ground-cedar.

(c) Provenance

Seed provenance may also have been a factor in survival, but as the origin of the stock was not always known, a proper relationship cannot be established. However, in those Scots pine plantations that were still in existence in 1952, mortality was lower where stock of German and Swedish origin was planted (Table 3).

The specific origin of most of the jack pine seed is not recorded, although the source of one lot is said to be "Manitoba and Saskatchewan". Presumably all may be designated as originating from these two provinces. However, an area of such magnitude would be expected to produce different seed qualities. As a result, it is probable that some of the variations in mortality might be directly attributed to the source of seed.

The same doubt exists as to the origin of the white spruce seed. The seedlings were grown at the nursery located at Indian Head, Saskatchewan, probably from a readily accessible local seed source, rather than from trees in the Spruce Woods Forest Reserve. This might partly account for the high mortality of the seedlings.

(d) Other Causes

Although the condition of the seedlings at the time of planting was apparently good in most instances, one Scots pine plantation did have very heavy mortality, attributed to "heating" of the seedlings during shipping and storing. One other known factor directly responsible for loss was a fire in 1906 which destroyed a Scots pine plantation.

Rate of Growth

(a) Scots Pine

A fairly thorough examination was made of site conditions in the plantations, and no major differences were revealed. The variations in growth and yield of the plantations cannot, therefore, be attributed to differences in soil or topography.

The best height and diameter growth, the highest survival rates, and the best form of Scots pine occur in the three plantations originating from German seed, in one of the two from Swedish seed, and in three of unknown provenance (Table 3 and Figures 4 and 5). The height growth in all seven plantations is comparable to the growth on a Class III site in Scotland (1), 40 feet in height at

TABLE 3.—SCOTS PINE PLANTATION
 SPRUCE WOODS FOREST RESERVE, SURVIVAL AND GROWTH PER ACRE

Plantation	2-05 ^c	3-06 ^c	4-07 ^c	8-16 ^c	12-16		26-20	45-22	61-24	62-24	70-25	80-25	81-25	83-25	84-25	86-25	87-25-1	87-25-2	90-26
					Thin- ned	Un- thin- ned													
Number of trees origi- nally planted.....	3,000	2,650	3,050	2,700	2,700	2,700	3,000	2,500	4,850	4,000	3,000	3,000	3,000	3,000	3,000	2,500		3,000	2,700
Survival one year after planting (%).....	85	80	65	95	95	95	50	80	75	80	80	80	80	85	80	75		75	75
Survival (% ^b)																			
1947.....	29	25	13	23															
1952.....	18	15	8	23		47	13	41	39	27	13	9	11	12	25	8		48	3
Number of trees living																			
1947.....	874	660	394	628							400	275	330	345	763	218		350	1,450
1952.....	534	400	243	615	575 ^c	1,258	382	1,032	1,905	1,060	727 ^a	240 ^a	142 ^a					530 ^a	72
Basal area (square feet)																			
1947.....	182.1	145.7	55.3	107.3							28.5	18.3	20.9	29.3	78.9	27.1		22.7	144.9
1952.....	150.4	113.3	72.4	106.2	99.7	155.3	61.3	70.6	192.3	95.2	Tot.	Tot.	Tot.					Tot.	3.0
Total volume (cubic feet)																			
1947.....	3,439	2,860	1,627	1,788							211	157	192	348	1,098	296		173	1,706
1952.....	2,921	2,278	1,386	1,772	1,833	2,484	977	832	2,170	1,051	50 ^a	12 ^a	4 ^a					27 ^a	24
Mean annual increment (cu. ft.).....	59.6	47.5	29.5	45.4							7.3	5.4	6.6	10.3	37.8	10.2			55.0
Av. diameter (inches)																			
1952.....	7.2	7.2	7.4	5.6	5.6	4.8	5.1	3.5	4.3	4.1	3.2	3.4	3.4	4.0	4.3	4.8		3.2	4.3
Average height of stand (feet) 1952.....	42	41	41	35	39	32	33	19	20	19	16	15	16	18	26	19		14	22

71

^a—Jack pine.

^b—Represents the percentage of original number planted.

^c—Thinned 1947—Volumes and Basal Areas based on stump diameters converted to d.b.h. and heights of living trees in 1952.

50 years of age. With one exception, however, the number of trees per acre, the basal area, and the total cubic foot volumes are less than on a Class III site, although the average diameter, in all cases, is higher.

Rate of growth on the other 11 plantations is very poor; the average height of the stands at 50 years of age is 30 feet or less, comparable to Site Index Classes IV or V in Scotland (Table 3). Seed sources of all plantations are not definitely known, but apparently most were from Scotland and Finland. Although average diameters of the trees on these plantations are larger than for the stands of the same site index classes in Scotland, the number of trees is less, resulting in a lower total cubic foot volume.

The lower density of the stands in some instances is due to a thinning operation in 1947 (Table 3). However, high mortality is the main cause of the low density, resulting in the development of orchard-type trees with rapid diameter growth but much taper.

(b) *Jack Pine*

The rate of growth of jack pine is not good, although it is better than for Scots pine. The average height of the dominants and codominants on each plantation was compared with the average height of dominants and codominants in stands in the Lake States (8). Three compared favourably with those on Site Index Class II, seven with Class III, and two with Class IV. In general, the average diameter of well-stocked plantations is less than that given for comparable age and site classes in the Lake States.

In the three best plantations, stems are comparatively straight, the trees are not too branchy, and form is good. In all others, form is only fair (Figures 6, 7 and 8).

(c) *Lodgepole Pine*

Rate of growth of the lodgepole pine is the poorest of all three species now surviving. Compared to jack pine of the same age, the average height of the dominant and codominant trees is as much as nine feet less, and the average stand diameter one and one-half inches less. This poor growth, together with the extremely poor form, makes the species of dubious value as a commercial tree in the area (Figure 9). However, the three plantations do yield at the present time an average of nine cords per acre, which is probably higher than many pulpwood-producing areas.

DISCUSSION

Results of the survey indicate that the development of the plantations in the Spruce Woods varied with the species, the origin of seed, the climatic conditions which immediately followed establishment, the planting method, and possibly the age of stock used.

On the basis of survival, 29 of the 62 plantations are complete failures. Assuming that a minimum stocking of 300 trees per acre is required to develop into a reasonable forest stand, five of the remaining 33 are also in poor condition.

From the standpoint of species survival, rate of growth, and form, jack pine planted in furrows is the most successful, white and Norway spruce are complete failures, while Scots pine and lodgepole pine are mediocre.

Information concerning the origin of most of the seed is lacking. However, it is evident that the survival, rate of growth, and form in the Scots pine plantations is best where stock originated from German and Swedish seed. It is possible that the differences in mortality and growth among the jack pine and the high mortality in the white spruce may also be due to seed provenance.

TABLE 4.—JACK PINE PLANTATION
 SPRUCE WOODS FOREST RESERVE, SURVIVAL AND GROWTH PER ACRE.

Plantation	5-13	7-10		10-16 ^{b,d}	11-16 ^d	20-18	22-18	47-22	56-24	57-24	58-24	63-24	55-25	
		Thinned	Un- thinned											
Number of trees originally planted.....	4,800	2,700	2,700	1,325	2,700	2,700	2,700	2,600	3,100	3,100	3,100	4,000	3,000	
Survival one year after planting (per cent).....	100 ^c	90	90	90	90	40	40	35	90	90	75	80	80	
Survival (per cent).....	(1947 1952)	40	61	35	14	33	5	28	74	57	48	79	28	
Number of trees alive.....	(1947 1952)	1,930	810	1,038	475 408 11 ^a	404 390 52 ^a	360	142	736	2,288	1,776	1,473	3,150	533
Basal area (square feet).....	(1947 1952)	194.0	89.8	145.1	70.4 70.0 Tot.	57.1 55.9 Tot.	64.0	15.7	76.6	182.2	171.7	150.1	198.1	76.2
Total volume (cubic feet).....	(1947 1952)	2,466	1,225	2,238	1,037 1,030 10 ^a	706 590 95 ^a	1,002	185	1,030	2,739	2,670	2,356	1,774	945
Mean annual increment.....		58.7	53.3	24.5	17.3	27.1	5.1	34.3	97.3	95.4	84.1	63.4	32.6	
Average diameter (inches).....	1952	4.3	4.5	4.0	5.2 3.6 ^a	4.8 4.1 ^a	5.7	4.5	4.4	3.8	4.2	4.3	2.8	4.1
Average height of stand (feet).....	1952	24	27	31	30	29	33	21	27	30	32	33	24	22
Average height of dominants and codominants (feet).....	1952	25	29	35	31	30	34	23	28	36	36	33	29	25

^a—Lodgepole pine

^b—Jack pine and caragana planted in alternate rows.

^c—Represents the percentage of original number planted.

^d—Thinned 1947—Basal Area and Volumes based on stump diameters converted to d.b.h., and heights of living trees in 1952.

TABLE 5.—LOGEPOLE PINE PLANTATION.
 SPRUCE WOODS FOREST RESERVE, SURVIVAL AND GROWTH PER ACRE.

Plantation	6-13	9-16	82-25
Number of trees originally planted	6,000	2,700	2,750
Survival one year after planting (per cent)	100	80	70
Survival (per cent)*	49	43	11
Number of trees alive	2,960	1,158	299
Basal area (square feet)	248.1	79.7	16.4
Total volume (cubic feet)	3,110	984	167
Mean annual increment	74.0	23.4	5.6
Average diameter (inches)	3.9	3.5	3.2
Average height of stand (feet)	23	22	15
Average height of dominants and codominants (feet)	25	26	20

* Represents the percentage of original number planted.

Drought and heat were the most important causes of mortality; Scots pine and the two spruce were the most seriously affected. Although most of the mortality in the white spruce plantations was attributed to these two factors, some of it was attributed to winter-kill. In the Scots pine plantations also there was considerable damage, and in some there was even mortality from winter-drying. The leaders probably dried out on two or three occasions and many of the stems today are forked and crooked. The wood also is soft and low in bending strength, so that further damage caused by drifting snow, particularly in young plantations, is extensive. Other species appear to be undamaged.

Insufficient information is available to determine whether seedling or transplant stock is better. Different-aged stock was planted but not always in the same year; consequently, comparisons between them cannot be made because of variations in climatic conditions.

The spacing generally used was 4 feet by 4 feet, which seems to be adequate under most conditions, but a spacing of 6 feet by 6 feet would be more economical and probably just as satisfactory. Present plantings by the provincial forestry service are of this nature.

The most successful method was to plant seedlings in ploughed furrows. In the few instances where they were set out without ground preparation the majority of the stock died, due primarily to grass competition. Rabbits were responsible for losses in the plantations established under young poplar stands.

The largest total volume per acre is on a small (one-tenth acre) lodgepole pine plantation, established in 1913. A Scots pine plantation set out in 1905 has the next highest total volume per acre. However, the average height and diameter of the Scots pine are almost twice that of the lodgepole pine stand; the large volume of the latter is due to the very large number of trees per acre. With these two exceptions, the total yields per acre of most jack pine plantations exceed those of Scots pine and lodgepole pine planted in the same year.

Tree form in three jack pine plantations is good, although in most it is only fair; Scots pine form is fair to poor and lodgepole pine form is poor. In open stands of all three species the trees are very branchy. Thinning and pruning of the jack pine should eventually produce saw-timber and pulp, although it is not expected that it will be suitable for poles. With the numerous defective trees in the Scots pine plantations and the small trees and poor rate of growth

in the lodgepole pine plantations, it is not expected that suitable saw-timber will be produced. They will, however, be useful for pulp and fuel.

Cone production for the three pines is very good, yet very little regeneration is present. It may well be that although germination does take place the mortality is exceptionally high. The results of these experiments indicate that even the planted stock has difficulty surviving in the area. White spruce reproduction in small openings along the protected north sides of existing plantations and native spruce clumps has been good (Figure 3). This may be due to increased moisture because of snow accumulation, and to shelter from the sun and drying winds. Conditions are favourable, therefore, not only for germination but for continued survival. The extreme climatic conditions which prevailed when white spruce was experimentally planted unfortunately seemed to discourage further work. The scattered natural stands, however, indicate that it will grow in the area, although not well. The height of 80-year-old trees is only 60 feet compared with 80 feet for similar-aged trees on the better sites of the B.18 Forest Section, and 70 feet for somewhat similar sites in the Riding Mountain National Park. It may be possible to plant successfully along the north sides of the existing plantations or stands and gradually extend the species across the sand plains, and eventually in this manner eliminate poor form typical of the existing trees.

SUMMARY

From 1904 to 1929 in the Spruce Woods Forest Reserve, the Forestry Branch set out several coniferous species on 204 acres, in 62 experimental plantations, for the purpose of determining the species and method most suitable for large-scale planting. The seedlings planted were Scots pine, jack pine, lodgepole pine, white spruce, and a small amount of Norway spruce. The plantations were set out on the sandy soils of the old Assiniboine river delta.

In a survey in 1952, the 33 surviving plantations were examined. In plantations of one acre or less, a 100 per cent diameter tally was made, while in those larger than one acre, rows were selected at random to give an approximate one-acre sample. In addition, information on the soil, site, cone production, and regeneration and vegetation was taken.

Though inadequate experimental design and infrequent remeasurements of plantations preclude comprehensive analysis of growth and mortality, the data from the 1952 survey and from past records indicate that:

1. Average survival in the plantations existing in 1952 was about 40 per cent for jack pine, 35 per cent for lodgepole pine, and 20 per cent for Scots pine.
2. Norway spruce and white spruce were complete failures.
3. Drought and heat were the chief causes of mortality, and white spruce, Norway spruce, and Scots pine were the species most affected.
4. Rabbits, pocket gophers and competition from grass caused additional losses to all species.
5. Winter-kill caused mortality and damage in Scots pine and white spruce plantations. Damage and mortality to the other species from this cause were negligible.
6. Planting in furrows and in cedar mats were the most successful techniques, the former being preferable. Underplanting in poplar was a failure, primarily due to the higher incidence of rabbits.
7. Jack pine exhibits the best growth rate and form.
8. Survival, rate of growth, and form in the Scots pine plantations are better where the stock originated from Swedish and German seed.

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FIGURE 2.—Excellent white spruce reproduction on the north side of Scots pine plantation 4-07.



FIGURE 3.—View of Spruce Woods Forest Reserve showing the scattered clumps of white spruce.



FIGURE 4.—Scots pine in plantation 26-20; not thinned. Note the poor form, knots and branches. Age: 32 years. D.B.H. (av.): 5.4 inches. Volume per acre: 977 cubic feet.



FIGURE 5.—Scots pine in plantation 2-05; thinned and pruned in 1947. Source of seed: Germany. Age: 47 years. D.B.H. (av.): 7.2 inches. Volume per acre: 2,921 cubic feet.



FIGURE 6.—Jack pine in plantation 7-16; thinned and pruned in 1947. Age: 36 years. D.B.H. (av.): 4.5 inches. Volume per acre: 1,225 cubic feet.



FIGURE 7.—Jack pine in plantation 20-18; not thinned. Age: 34 years. D.B.H. (av.): 5.7 inches. Volume per acre: 1,002 cubic feet.



FIGURE 8.—Jack pine in plantation 22-18; not thinned. Note the open nature of the stand, 142 trees per acre. Age: 34 years. D.B.H. (av.): 4.5 inches. Volume per acre: 185 cubic feet.



FIGURE 9.—Lodgepole pine in plantation 9-16; not thinned. Note the heavy branching. Age: 36 years. D.B.H. (av.): 3.5 inches. Volume per acre: 984 cubic feet.

Photos by C. L. KIRBY



APPENDIX

TABLE 1.—STAND TABLES 1952
 AVERAGE NUMBER OF TREES PER ACRE FOR JACK PINE IN PURE STANDS

D.h.h. (inches)	Plantation Number										
	5-13	7-16		20-18	22-18	47-22	56-24	57-24	58-24	63-24	8.5-25
		Thinned	Unthinned								
1.....	20		15			16	40	37	33	300	37
2.....	170	8	205	16	16	56	333	152	106	940	92
3.....	300	62	385	30	26	104	598	340	303	1,400	148
4.....	660	345	558	38	42	236	818	610	518	450	289
5.....	410	350	410	98	30	240	403	460	336	60	137
6.....	250	42	75	84	18	76	85	157	100		68
7.....	20	2	10	65	8	8	10	19	52		11
8.....	10			17	2				24		
9.....				10							
10.....				2							
11.....											
Total.....	1,930	809	1,658	360	142	736	2,287	1,775	1,472	3,150	832

TABLE 2.—STAND TABLES 1952
 AVERAGE NUMBER OF TREES PER ACRE FOR SCOTS PINE IN PURE STANDS

D.b.h. (inches)	Plantation Number														
	2-05	3-06	4-07	8-16	12-16		26-20	45-22	61-24	62-24	83-25	84-25	86-25	87-25-2	99-26
					Thin- ned	Un- thinned									
1.....	7		1	21	2	105	15	124	238	80	32	45	9	52	41
2.....	16	3	3	73	32	228	52	300	238	230	59	110	18	155	21
3.....	45	19	22	96	72	282	68	188	333	120	83	172	43	285	6
4.....	69	50	35	128	165	298	96	92	381	220	67	190	50	492	3
5.....	96	76	48	131	185	230	64	60	238	140	34	87	40	181	1
6.....	90	101	40	106	98	102	54	44	95	40	5	40	17		
7.....	88	82	39	44	20	12	26		48		1	7	3		
8.....	72	42	17	13			4						2		
9.....	31	22	14	3			3								
10.....	19	5	11												
11.....		1	8												
12.....			3												
13.....	1														
Total.....	534	401	241	615	574	1,257	382	1,032	1,905	1,060	346	764	218	1,450	72

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TABLE 3.—STAND TABLES 1952
 AVERAGE NUMBER OF TREES PER ACRE FOR MIXED JACK PINE AND LODGEPOLE PINE

D.b.h. (inches)	Plantation Number					
	10-16			11-16		
	Jack pine	Lodgepole pine	Total	Jack pine	Lodgepole pine	Total
1.....	2	.....	2	4	1	5
2.....	16	3	19	31	9	40
3.....	39	3	42	47	22	69
4.....	75	5	80	105	23	128
5.....	171	1	172	107	19	126
6.....	110	.....	110	66	7	73
7.....	46	.....	46	24	1	25
8.....	9	.....	9	7	.....	7
9.....	1	.....	1	.....	.....	.....
10.....	.....	.....	.....	.....	.....	.....
Total.....	469	12	481	391	82	473

TABLE 4.—STAND TABLES 1952
 AVERAGE NUMBER OF TREES PER ACRE FOR LODGEPOLE PINE IN PURE STANDS

D.b.h. (inches)	Plantation Number		
	6-13	9-16	82-25
1.....	40	.....	36
2.....	180	198	79
3.....	1,050	471	96
4.....	970	331	58
5.....	550	133	21
6.....	170	19	7
7.....	.....	5	2
8.....	.....	1	.....
Total.....	2,960	1,158	299

TABLE 5.—STAND TABLES 1952.

AVERAGE NUMBER OF TREES FOR MIXED SCOTS PINE AND JACK PINE

D.b.h. (inches)	Plantation Number											
	79-25			80-25			81-25			87-25-1		
	Scots pine	Jack pine	Total	Scots pine	Jack pine	Total	Scots pine	Jack pine	Total	Scots pine	Jack pine	Total
0.5	8	608	616	94	213	213	100	78	78	100	100	100
1	142	100	242	83	17	111	122	56	113	355	75	355
2	126	18	144	62		83	63	7	122	100		230
3	83		83	29		62	17		63	45		100
4	37		37	7		29	18		17	45		45
5	4		4			7	2		18	5		45
6									2			5
7												
8												
9												
Total	400	726	1,126	275	230	505	328	141	469	350	530	880