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FACTORS AFFECTING SURVIVAL AND GROWTH OF RED PINE PLANTATIONS IN SOUTHEASTERN MANITOBA

by
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Factors Affecting Survival and Growth of Red Pine Plantations in Southeastern Manitoba

by
R. A. Haig and J. H. Cayford[1]

INTRODUCTION

Within its natural range red pine (*Pinus resinosa* Ait.) has long been recognized as a desirable species for commercial planting because of its usually rapid growth rate, good form, and relative freedom from serious insect and disease damage. It was first planted on the Sandilands Forest Reserve in southeastern Manitoba in 1927 and by 1958 the number planted exceeded one million. In 1958 forty-one plantations set out between 1931 and 1946 were examined to determine their survival and growth. At the same time limited observations were made of some of the most important factors which had apparently affected their development.

DESCRIPTION OF AREA PLANTED

The Sandilands Forest Reserve is situated in the western portion of the Rainy River Section L. 12, of the Great Lakes-St. Lawrence Forest Region (Rowe, 1959). With the exception of an outlier on Black Island in Lake Winnipeg, the reserve marks the northwestern limit of the natural range of red pine (Anon., 1956b). The regional climate is characterized by cold winters and mild summers, with January and July mean temperatures being 0°F and 65°F, respectively (Anon., 1957). The average annual precipitation is 21 inches, and the average length of the frost-free period between 80 and 100 days, both of these being below the levels prevailing over most of the range of the species. (Anon., 1957; Rudolf, 1957.)

The plantations examined were located on a large undulating plateau which occupies the central portion of the reserve and is 200 to 300 feet higher than the surrounding country. The soils, which are deep and sandy textured, have developed from outwash and morainic deposits which, because of their elevation, were not modified by the waters of post-glacial Lake Agassiz (Anon., 1956a). The soil profiles are poorly developed podzols and the sites may be classified as dry and excessively drained.

The planting areas originally supported jack pine (*Pinus banksiana* Lamb.) stands but were mostly denuded as a result of logging or fire. They were gently rolling, open, grassy areas surrounded by jack pine stands of various ages. In some instances there was a scattering of jack pine on the actual planting sites.

THE PLANTATIONS

The study was confined to the 41 plantations set out between 1931 and 1946. Inadequate records were available for the 1927 and 1930 plantations and those set out after 1946 were too young to provide reliable indications of their probable development. The plantations examined had a combined area of 229 acres and varied in size from 0.5 to 48 acres with approximately one-half of them occupying less than two acres each.

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About 613,000 seedlings were planted between 1931 and 1946, of which 42,000 were used for refilling purposes. Planting stock was produced in Manitoba nurseries from local seed and was nearly all in the 2-2 age class. Planting was done in the spring by hand planting in ploughed furrows, and spacing was generally 4 by 4 feet. With the exception of one alternate-row mixture with Scots pine (*Pinus sylvestris* L.), all plantations were set out as pure stands.

METHOD OF EXAMINATION

In each plantation a diameter tally was made on a random sample ranging from 4 to 100 per cent of the area. Generally, the percentage sample tended to vary inversely as the size of the plantation, but this procedure was modified by the level of survival, a larger sample being taken where stocking was low and patchy and a smaller sample where it was high and uniform. In each plantation total height to the end of the 1957 growing season, 1957 leader growth, and d.b.h. were measured on 6 to 15 sample trees selected to sample the range of diameters.

General notes were made and additional measurements taken to investigate some of the factors which appeared to have affected plantation development. Soils and minor vegetation were described for each plantation.

RESULTS

Table 1 is a summary showing for each year the number of plantations established, total area planted, number of years since planting, average survival in both trees per acre and per cent, and average diameter and height. Although the plantations occupy 229 acres, the total area planted is considered as 267 acres because 38 acres were re-planted due to low survival of the original stock.

All plantations with at least 400 trees per acre, approximately equivalent to a 10-foot spacing, were considered to be satisfactorily stocked. In Ontario, Stiell and Bickerstaff (1959) have found the rate of merchantable volume growth in young red pine plantations to be only slightly less at this level of stocking than in much denser stands.

In 1958 there were 60 acres of successful plantations, based on survival of individual plantations, or about 26 per cent of the planted area. Excluding portions of a number of plantations destroyed by fire in 1949, 42 per cent of the area planted was satisfactorily stocked.

Average heights of the plantations were much less than those of red pine plantations of the same age in Ontario and the Lake States (Rudolf, 1950; Stiell, 1955). Fifteen years after planting, average height was only eight feet for Sandilands plantations as compared to 17 feet for Ontario and Lake States plantations. However, in spite of the low survival and comparatively slow growth of the Sandilands plantations, excellent form and good general health were characteristic of the surviving trees (Figures 1 and 2).

TABLE 1.—SUMMARY OF 1958 RESULTS, 1927-1946 RED PINE PLANTATIONS, SANDILANDS FOREST RESERVE

Establishment data				Results, 1958[1]				
Year planted	Number of plantations	Area (acres)	Number of years since planting	Average number of trees per acre	Average survival (per cent)	Average d.b.h. (inches)	Average height (feet)	Remarks
1927	—	—	31	—	—	—	—	Only records available are number of trees planted.
1930	—	—	28	—	—	—	—	Only records available are number of trees planted.
1931	1	1.5	27	0	0	—	—	Not located, probably a failure.
1932	4	33.5	26	<50	< 1	2.1	11.6	
1933	8	16.4	25	430	16	1.9	12.7	
1934	10	16.1	24	290	11	1.8	10.8	
1935	4	5.7	23	1,038	38	1.6	10.4	
1936	1	1.1	22	530	19	1.1	7.6	
1937	3	28.0	21	2,380[2]	89[2]	1.6	9.8	Refilled with rP (15.2 acres) and ScP (12.8 acres) in 1941. All but 1.0 acre of original 28.0 acres of plantations destroyed by fire in 1949.
1938	2	24.7	20	2,200[2]	—[3]	1.2	8.2	Refilled with rP (11.1 acres) and ScP (11.0 acres) in 1941 and 1942. Half of each plantation burned in 1949.
1939	2	11.8	19	2,070	—[3]	0.6	5.7	Refilled with rP (11.8 acres) in 1943.
1940	1	3.2	18	960	64	1.1	8.3	Alternate row mixture of rP and ScP.
1943	2[4]	16.7	15	1,263	58	0.7	6.2	
1944	1	7.3	14	2,800[2]	82[2]	0.9	7.0	All but 0.5 acre of plantation destroyed by fire in 1949.
1945	1	14.9	13	1,855[2]	69[2]	0.8	6.7	All but 3.0 acres of plantation destroyed by fire in 1949.
1946	1	48.0	12	960[2]	65[2]	0.5	5.0	All but 5.0 acres of plantation destroyed by fire in 1949.
	Average			850[2]	32[2]			

[1] As most of the measurements were made early in 1958, age and height were determined to the end of the 1957 growing season.
[2] Based on the portions of plantations not destroyed by the 1949 fire.
[3] Average survival was not calculated because number of refills was unknown.
[4] One of the 1943 plantations was originally planted with Scots pine in 1939 and subsequently refilled with red pine.
Note—rP = red pine
ScP = Scots pine

Figure 1. Red pine plantation 1-38. Two tall trees to left are survivors of original 1938 planting; the remainder are refills planted in 1942.

Figure 2. Red pine plantation 1-43. This is probably the best plantation. Survival is 83 per cent and average height 10 feet.

FACTORS THAT AFFECTED RESULTS

The plantations were set out on dry sandy and gravelly soils and in many instances they were exposed to desiccating winds and extreme insolation. These sites could not be considered optimum for red pine and there is considerable evidence to suggest that on moister and more sheltered sites the overall performance of the plantations would have been superior (Rudolf, 1957). However, as some of the plantations are expected to develop into satisfactory merchantable stands, the more important factors affecting their development are discussed.

Drought

The low percentage of successful plantations (even with fire losses excluded) is attributed largely to drought. Normal growing season (May to September) precipitation on the Sandilands Forest Reserve [2] is at the lower limit indicated by Rudolf (1957) for the natural range of red pine. Lake States studies have shown that the amount and distribution of rainfall during the first growing season are the most important factors affecting plantation survival (Anon., 1935; Stoeckeler and Limstrom, 1950).

During the years 1931 to 1946 growing season rainfall varied from 4.0 inches below to 4.9 inches above normal. Figure 3 shows average survival in 1958 of the red pine planted each year during this period.[3] Also shown is the total May to September precipitation for each year. Plantations set out during years when rainfall was normal or below usually had less than 40 per cent survival by 1958. In years when May to September precipitation was more than 14 inches, survival ranged from about 60 to 90 per cent. Exceptions to the general trend occurred in 1940 and 1946 when survival was high despite low precipitation. In view of the large number of factors which may affect plantation survival, the degree of correlation between growing season precipitation and survival in 1958 is considered to be remarkably high.

This correlation is further substantiated by examinations made by the Manitoba Forest Service at the end of the first growing season after planting. Mortality ranged from 14 to 96 per cent (average about 50 per cent) for trees planted in the 1930's, and 1 to 25 per cent (average about 10 per cent) for those planted in the 1940's. Drought was reported to be the main cause of the high mortality during the 1930's.

Mean growth rate of the younger plantations was slightly superior to that of the older ones, a situation contrary to the normal pattern for trees of these ages. As current annual height increment of all plantations was reasonably uniform (about one foot) it appeared that the slow growth of the older trees occurred early in their history. To verify this, age counts were made at breast height and at stump height on 252 trees growing in many of the plantations. It was found that trees planted in the 1930's required an average of about nine years to reach one foot while those planted in the 1940's reached the same height in about 4.5 years. Low precipitation during the 1930's and above average precipitation during the 1940's (Figure 3) are believed responsible. Other studies have also shown similar relationships between height growth and precipitation (Motley, 1949; Williams, 1958).

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[2] Average of precipitation data for the two closest weather stations, Sprague and Winnipeg (12.8 inches).

[3] Survival of 1937, 1938, 1944, 1945, and 1946 plantations is based on the survival of the portions that escaped the fire in 1949.

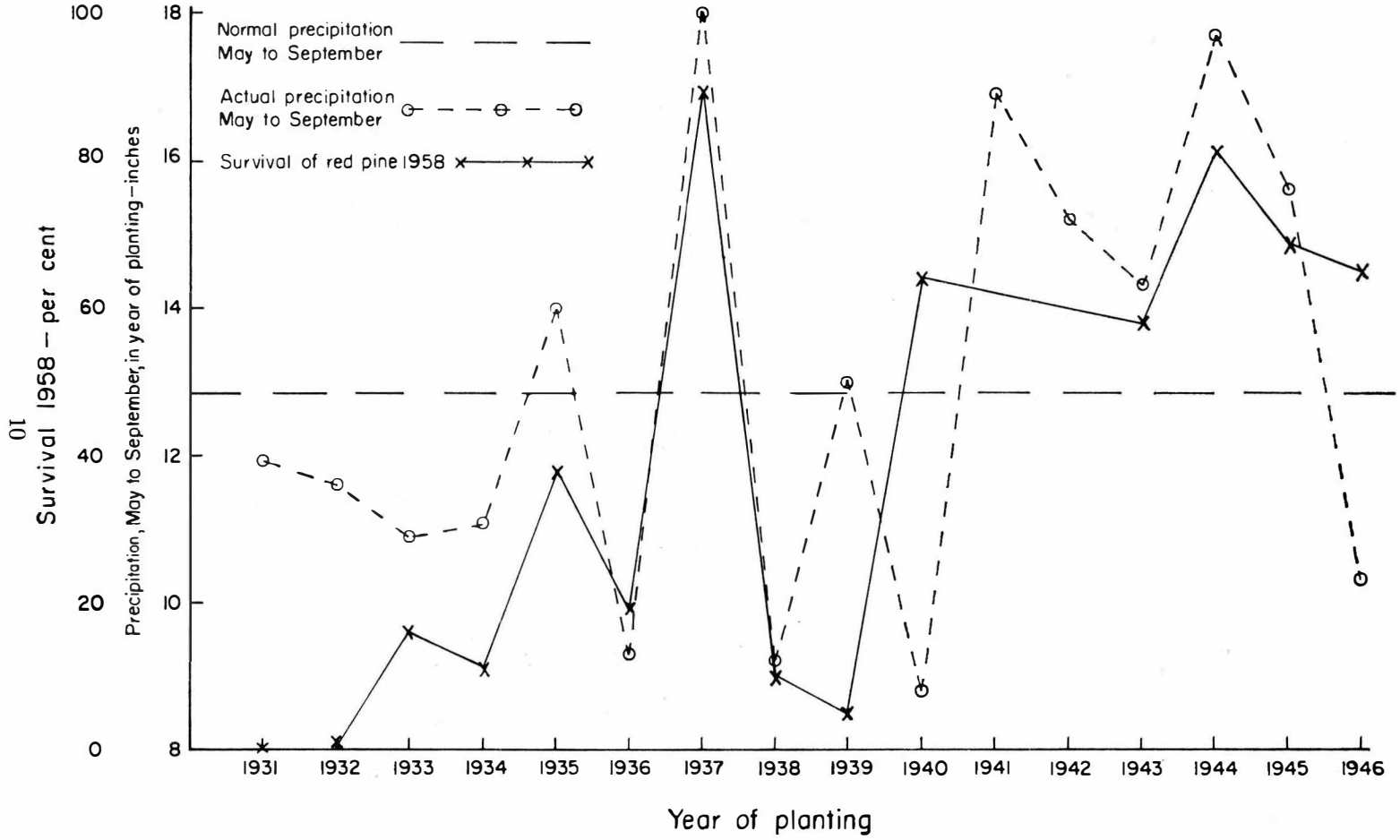

Figure 3. Precipitation, May to September, and survival of red pine plantations, 1958, Sandilands Forest Reserve.

Plantation Density

Survival of most of the plantations was patchy, and both diameter and height showed an increase with increasing plantation density (Figures 4 and 5). Careful examinations were made in several plantations to determine if any observable site factors were responsible for the differences in survival, but, except in a few of the 1934 plantations, none were apparent. The largest trees occurred in the densest clumps of survivors, while scattered open-grown trees were below average in size. Measurements made on three plots in plantation 1-35,[4] selected to sample the density range, are summarized in Table 2 and show the effect of plantation density on growth.

TABLE 2.—EFFECT OF PLANTATION DENSITY ON GROWTH OF RED PINE
(Plantation 1-35)

Trees per acre	Basal area per acre	Average d.b.h.	Average height
Number	sq. ft.	inches	feet
1,540	37.1	2.1	11.6
1,130	20.6	1.8	10.5
340	2.5	1.1	8.0

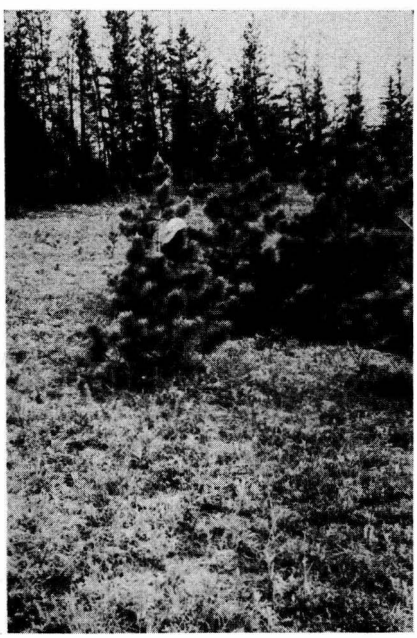

Figure 4. Red pine plantation 1-35. The growth of open-grown trees is very poor (notice cap at breast height).

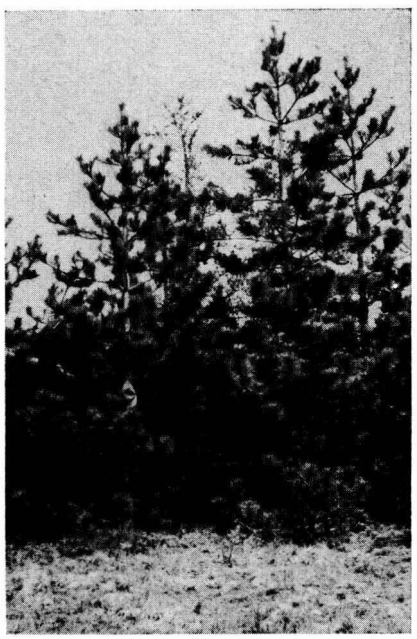

Figure 5. Red pine plantation 1-35. The growth of densely grown trees is good (cap at breast height).

[4] The first figure is the plantation number; the last two indicate the year of planting.

On dry sites on the Sandilands Forest Reserve, moisture is at a minimum for the growth and development of red pine. It is believed that moisture conditions during the growing season were more favourable in the clumps than where trees were scattered. Observations indicated that, due to drifting, snow accumulation was greater in the clumps, and due to shading, snow melt was considerably delayed.

Jack Pine

The occurrence of jack pine on planting areas at the time of planting affected the development of red pine by increasing initial survival and subsequently reducing growth. The same effects were noted in the Lake States by Stoeckler and Limstrom (1950). In plantation 6-33, on a portion where there were 230 young jack pine trees per acre at the time of planting, survival in 1958 was 750 trees per acre. Where there were only 25 jack pine trees per acre, red pine survival was only 45 trees per acre. This finding suggests that the jack pine provided some protection from the sun and wind, and thus aided the survival of the planted trees.

However, the presence of an overstorey of jack pine had an adverse effect on height growth (Figure 6). In 1958, plantation 1-38 had a scattering of 40- to 50-year-old "orchard-type" jack pine ranging from 7 to 10 inches in diameter and from 20 to 40 feet in height, and their effect is shown in Figure 7. It is

Figure 6. Plantation 1-38 (20 years after planting), showing severe suppression of red pine under a 40- to 50-year-old jack pine.

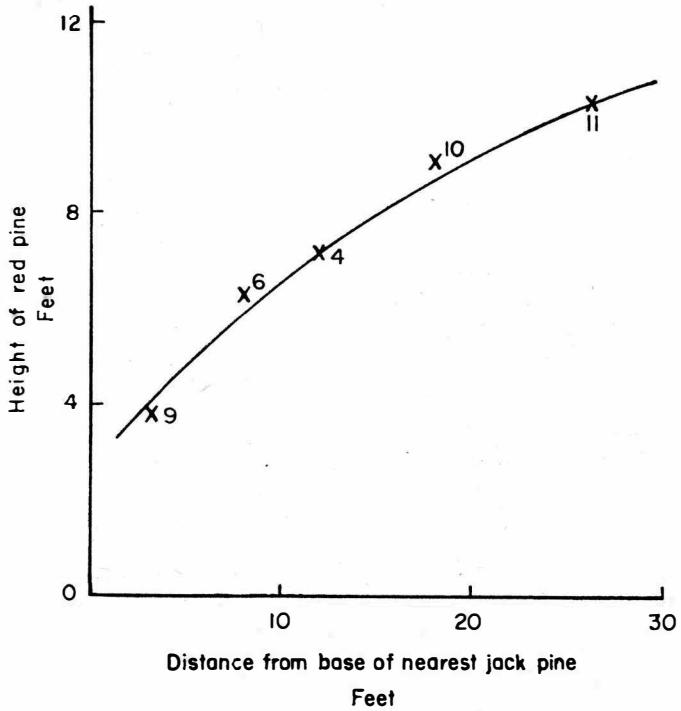

Figure 7. Effect of a 40- to 50-year-old jack pine overstorey on height of 20-year-old red pine (based on measurement of 40 trees in plantation 1-38).

obvious that suppression of height growth increased as distance from the jack pine decreased. The average height of free-growing red pine was about 11 feet, but within 5 feet of a jack pine tree average height was only 4 feet.

In every plantation there were varying numbers of jack pine that had regenerated naturally in the planting furrows. Although these trees were slightly younger than the red pine, in all instances they had outgrown the latter by a wide margin. In plantation 2-34 there were approximately 440 jack pine per acre with an average age of 24 years, an average diameter of 3.3 inches, and an average height of 21 feet. The red pine, which were 28 years old (total age), had an average diameter and height of 1.5 inches and 10.9 feet, respectively. However, in spite of its having attained a greater height, observations indicated that the jack pine did not appear to have had a suppressing effect on the growth of the planted trees. To further investigate the effect of young jack pine, the heights of 24 red pine trees located at various distances from the nearest jack pine were measured in plantation 2-34 in an area where plantation density was reasonably uniform. Within a distance of about four feet there was a slight reduction in height of red pine, but beyond this distance it was quite normal. In fact many of the largest red pine were observed growing at distances of from four to six feet from a jack pine tree.

Soil Conditions

Some of the variations in survival and growth appeared to be due to differences in local soil conditions which occurred in a small number of the 1934

plantations. As mentioned earlier the plantations were set out on poorly developed sandy soils which were classified as dry and excessively drained. In a few plantations a strongly calcareous C horizon of compacted gravel occurred at depths varying from 6 to 48 inches. A generalized description of such a soil is as follows:—

A_{00} —$\frac{1}{8}$ to 0 inch; dead grass and red pine needles.

A_0 —Trace of humus.

A_2 —0 to 2 inches; dark gray brown[5]; fine sand; structureless; scattered grass roots; stone-free; pH 6.4.

A_2-B_1 —2 to 5 inches; light brownish-yellow; medium sand; very slight compaction; maximum zone of red pine rooting; pH 6.1.

B_1 —5 to 13 inches; light brownish-yellow; medium sand; slight compaction; scattered red pine roots; scattered pebbles ($\frac{1}{16}$ inch diam.); pH 6.0.

B_2 —13 to 26 inches; brownish-yellow to yellow; medium to coarse sand; structureless; scattered red pine roots; scattered stones (3 to 6 inches diam.), limestone and granitoid; pH 6.3.

C_{1p} —26 to 31 inches; heterogeneous colour, fine material brown to yellowish-brown, gravelly material is white, red, and black; compacted boulder horizon, with some fine sand; granitoid and limestone stones up to 6 inches diam.; few roots; calcareous; pH 8.0.

C_2 —31+ inches; very pale brown; fine sand; structureless; numerous small limestone pebbles; pH 7.5.

Where the gravel was less than 12 inches below the surface, survival was invariably poor. The converse was not always true, as general weather conditions rather than local soil conditions were the primary factor causing mortality.

The depth to the calcareous gravel layer also affected height growth (Figure 8). Figure 9 shows for a selected number of trees growing in the 1934 plantations, their height and the depth to the gravel layer adjacent to the tree. Although density was probably a contributing factor, Figure 9 indicates that height growth increased with increasing depth to calcareous gravel. Height varied from 3 feet on the shallowest extreme to 21 feet on the deepest and no trees taller than 7 feet were found where the calcareous gravel layer occurred at depths of less than 15 inches.

Other Factors

In general the plantations appeared healthy, with little evidence of biotic or climatic damage. In 1957, "needle droop" was reported in several plantations. The symptoms were drooping and discolouration of the current year's foliage, most commonly on the leader only, but occasionally on some of the lateral branches also. The most commonly reported cause of needle droop is a physiological water shortage which may occur early in the growing season when the tree leaders are elongating rapidly and water requirements are high (Patton and Riker, undated). In 1958 it was noted that the affected trees had made only about one-half their normal leader growth during 1957. However, because only a very few leaders were killed, it appeared that little permanent damage was done.

[5] Soil colours were determined using a Munsell colour chart with dry soil.

Figure 8. Red pine plantation 3-34. Location of calcareous gravel layer varies from 24 inches from surface on right to 7 inches on left. Survival and growth are correlated with depth of gravel layer.

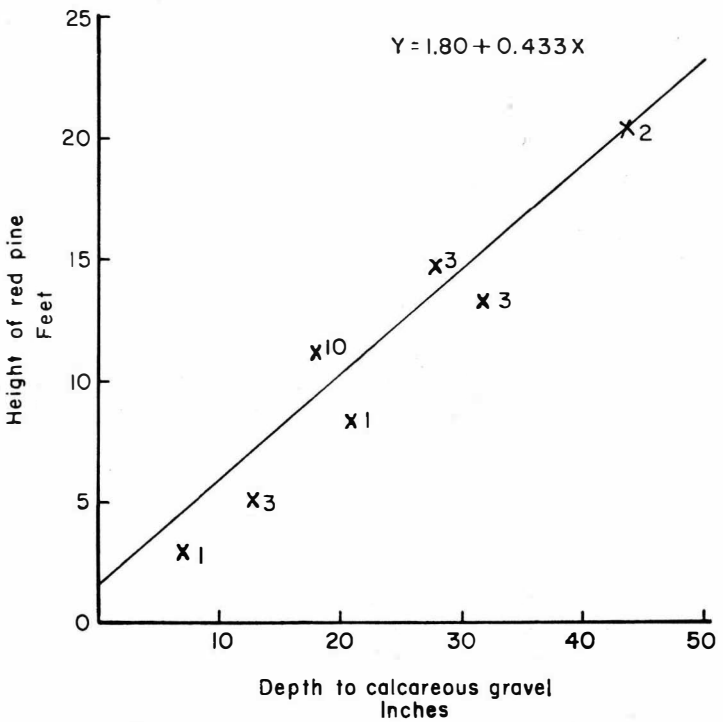

Figure 9. Effect of depth to calcareous gravel on height of red pine, 1934 plantations.

In 1957 a jack pine budworm (*Choristoneura pinus* Free.) outbreak occurred on the Sandilands Forest Reserve, and red pine trees were lightly defoliated where they occurred in the immediate vicinity of mature jack pine.

Subsequent to the examination in 1958 many of the plantations were damaged by glaze during a storm in November 1958. Considerable damage occurred and an investigation of its extent and of the recovery of the damaged trees was carried out during 1959. Results will be reported later.

SILVICULTURAL APPLICATION

It has been shown that the survival of the plantations was low and that their growth rate was considerably below average for red pine throughout most of its natural range. However, the form and general health of the surviving trees were excellent, and there is no reason to believe that with a more careful choice of sites the plantations would have shown more favourable results. A natural red pine stand on a moderately fresh, loamy sand not far from the general vicinity of the planting had dominant heights of 65 feet at 65 years, while in an adjacent stand of the same age on dry, gravelly sand (similar to the soils which were planted) dominant heights were only 50 feet. This suggests that the growth of the plantations was below optimum for the reserve.

Further planting of red pine on the reserve should be undertaken primarily on moderately fresh to fresh sites on sandy-loam to sandy soils. Dry sites should ordinarily he planted to jack pine, as it has demonstrated its ability to perform satisfactorily on them.

The development of the better plantations indicates that red pine may be grown even on dry sites, with the exception of areas where a calcareous gravel layer occurs within two feet of the surface. However, to attain a satisfactory degree of success, the precautions discussed below probably should be observed.

Although it is not possible to forecast the amount of rain which will fall in a given growing season, the planting of red pine should be attempted only when the soil is moist and current weather conditions are favourable. In this way some of the losses due to drought may be avoided.

Planting of red pine where there is a scattered overstorey, or in small openings in standing timber, is preferable to planting on large open areas where exposure is extreme. However, to avoid suppression, overhead shade should be removed within a few years of plantation establishment.

To obtain the benefits of early stand closure, red pine probably should not be planted at spacings greater than 6 by 6 feet. Where necessary, refilling should be carried out promptly in order to achieve the well-stocked stand condition which is evidently essential for satisfactory growth on dry sites in this area.

SUMMARY

Between 1927 and 1958 over one million red pine were planted on the Sandilands Forest Reserve. In 1958, 41 plantations set out between 1931 and 1946 on dry, sandy soils were examined. Although the plantations occupied 229 acres, the total area planted is considered as 267 acres because 38 acres were re-planted. On the basis of 400 trees per acre in 1958 representing satisfactory stocking, 26 per cent of the planting was successful, and excluding portions destroyed by a fire in 1949, 42 per cent was successful.

With the exception of fire, drought during the first growing season after planting was considered to be the chief cause of failure. Height growth was also affected by precipitation, and was slower in the decade 1931 to 1940, when the average growing season precipitation was below normal, than in the decade 1941 to 1950 when it was above normal. A partial overstorey of jack pine increased survival but reduced height growth by suppression. Young jack pine of about the same age as the planted trees outgrew the latter by a considerable margin but did not appear to have suppressed them. The presence of a calcareous gravel layer close to the surface reduced survival and growth in a few plantations.

The overall performance was below average for red pine throughout most of its range. While some of the difference was undoubtedly due to unfavourable climatic conditions, the excessively dry planting sites were at least partly responsible. However, the surviving plantations showed good form and health and there is every reason to believe that where stocking was adequate they will develop into satisfactory merchantable stands. Future plantings of red pine probably should be concentrated on somewhat moister sites than the ones chosen for these plantations. Some suggestions are made for improving the results of planting on dry sites.

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