CANADA
Department of Forestry

CONTINUOUS PLANTING OF WHITE SPRUCE THROUGHOUT THE FROST-FREE PERIOD

by
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Forest Research Branch
Technical Note No. 117
1962

Published under the authority of
The Honourable Hugh John Flemming, P.C., M.P.,
Minister of Forestry
Ottawa, 1962

ROGER DUHAMEL, F.R.S.C.
QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1962

Cat. No. Fo47-117

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53320-8—1½

Continuous Planting of White Spruce Throughout the Frost-Free Period

(Project K-67)

by

R. F. Ackerman and H. J. Johnson[1]

INTRODUCTION

Although the spring and fall months have long been considered the best for forest planting, confining reforestation to these seasons has often resulted in administrative difficulties owing to the short duration of planting periods. For this reason a test of the practicability of planting white spruce (*Picea glauca* (Moench) Voss. var. *Albertiana* (S. Brown) Sarg.) throughout the frost-free period was initiated at the Kananaskis Forest Experiment Station in 1952.

Preliminary results, published by Crossley (1956), are summarized below.

1. Mortality was acceptably low throughout the whole planting season, but was highest whenever the soil at the time of planting was powder dry.
2. Height growth was variously depressed, depending on the period of planting.

These results were based on a short period of observation and could not be considered conclusive. Measurement of growth and mortality was continued for an additional five-year period to test more fully the conclusions and hypothesis presented by Crossley.

METHODS AND MATERIALS

The study was undertaken on the Kananaskis Forest Experiment Station (51° 00′ N, 115° 10′ W) located at an elevation of 4,500 feet in the Subalpine Region of Alberta (Rowe 1959).

The planting site is a burned-over flood plain bordering the Kananaskis River. The soil is an excessively drained alluvium which changes at an approximate depth of two feet from a sandy loam to a coarse gravelly and cobbly outwash. Productivity of the site is considered well below average for white spruce.

A complete description of methods and materials is given by Crossley (1956). Briefly the following was done.

A 6 × 6 latin square design was used to eliminate possible effects of varying soil fertility and shelter from the vegetation bordering the planting site. Each cell of the square contains one month's planting of the six-month period May to October, inclusive. Fifty-six trees were planted in each cell at the rate of 14 each week of the treatment month. A month's planting consists therefore of 336 trees.

To assess the effects of yearly changes in climate, the study was repeated in 1953 and 1954.

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The same planting stock was used each year of the experiment. In 1952 this stock was 3-3, in 1953, 3-4 and in 1954, 3-5. The stock was graded so that the supply was similar in size for all three years. Average top length of the stock was 10.3 inches and average top/root ratio was 0.83. Stock was hole-planted at the rate of 56 trees per man hour.

Differences in mortality and height growth attributable to month of planting were investigated by analysis of variance (Appendices I and II). Differences between individual treatment means were examined by the method of J. W. Tukey (Snedecor 1956).

RESULTS

Mortality

Per cent mortality five years after planting is shown by month and year of planting in Table 1.

Table 1. Per Cent Mortality Five Years After Planting, by Year and Month of Planting

Month of Planting	Year of Planting			
	1952	1953	1954	All
May	2.7	2.1	4.5	3.0
June	3.9	13.4	4.2	7.1
July	1.2	8.9	19.6	9.8
August	5.1	24.7	9.2	13.1
September	5.6	19.6	21.1	15.5
October	8.0	13.7	37.2	19.6
All	4.5	13.7	16.4	

The most important feature of these data is the generally low mortality of all plantations during the first five-year period. Maximum mortality for a year's planting occurred in the 1954 plantation with a loss of only 16.4 per cent. Maximum mortality for a month's planting was 37.2 per cent (October, 1954) and for a week's planting 48.8 per cent (October, 1954).

The data were further summarized according to seasonal mortality (Table 2). Spring was considered that period prior to bud flushing and commencement of apical growth; summer, the period between bud flushing and cessation of apical growth; and fall, the period subsequent to summer and prior to the frequent occurrence of freezing temperatures. As might be expected, the dates of initiation, cessation and duration of these periods varied between the three years of planting.

Table 2. Per Cent Mortality Five Years After Planting by Year and Physiological Season of Planting

Season of Planting	Year of Planting		
	1952	1953	1954
Spring	3.2	3.8	4.8
Summer	3.6	11.2	7.1
Fall	5.0	19.4	23.3

Averaging values for all three years, percentage mortality increased progressively with deferment of the planting date from May through to October. The effect of month of planting varied from year to year, however, being most evident in the 1954 plantation. Also, the planting months resulting in significant difference varied from year to year (Appendix 1). The inconstancy is not surprising since weather and soil moisture conditions prevailing on any given calendar day, week or month will vary from year to year.

In spite of the variability in the results each year, wherever significant differences occurred between planting months the earlier planting resulted in lower mortality.

Height Growth

Average total height growth for the five-year period following planting is shown in Table 3 by year and month of planting and in Table 4 by year and physiological season of planting.

Table 3. Average Total Height Growth in Inches Five Years After Planting by Year and Month of Planting

Month of Planting	Year of Planting			
	1952	1953	1954	All
May	11.2	12.6	9.0	10.9
June	11.3	8.8	11.9	10.7
July	9.6	8.9	8.6	9.0
August	7.4	8.1	6.8	7.4
September	7.8	7.9	6.7	7.5
October	6.8	6.5	7.2	6.8
All	9.0	8.8	8.3	

Table 4. Average Total Height Growth in Inches Five Years After Planting by Year and Physiological Season of Planting

Season of Planting	Year of Planting		
	1952	1953	1954
Spring	10.9	12.3	9.7
Summer	11.5	8.7	10.3
Fall	8.0	7.7	7.4

Averaging values for all years, height growth decreased progressively from the May to the October plantings. Statistical significance is confined, however, to differences between May-June and subsequent months (Appendix 2).

There were year-to-year variations in the months showing significant differences in height growth. As with mortality, all significant differences between months favour the earlier month.

The effect of month of planting was still evident statistically in the current height growth five years after planting.

DISCUSSION

Mortality was acceptably low regardless of planting date; therefore planting white spruce throughout the frost-free period is feasible in the Subalpine Region if the three years tested are considered representative. Any planting program, however, should be sufficiently flexible to avoid extended periods of drought and critically low soil moisture.

Precipitation and mean temperature for the Kananaskis Forest Experiment Station, recorded approximately ten miles from this planting site, are shown in Table 5 for the three planting years and the 21-year period 1940 to 1960. Precipitation recorded at the planting site for the period May 24 to September 17 is also shown. The data indicate that although precipitation varied markedly from normal during some months, total precipitation and mean temperature for the six-month study period were near normal each year. On the average, May and June have the greatest precipitation while September and October have the least, and this pattern was accentuated during the study period by abnormally low rainfall in October and high rainfall in June.

Survival depends upon the weather and soil moisture conditions during and after planting and the ability of seedlings to rapidly regenerate damaged root systems. Greatest success can be expected, therefore, if stock is planted at a time when the physiological condition of the plants is conducive to rapid root initiation and growth, and temperature and moisture conditions are favourable.

Table 5. Precipitation and Mean Temperature—Kananaskis Forest Experiment Station

Month or Period	Year			Period	
	1952	1953	1954	Mean 1952-54	Mean 1940-60
PRECIPITATION: inches					
May	2.92	3.32	3.15	3.13	3.19
June	*7.49*	*7.19*	3.33	6.00	4.41
July	3.18	2.08	*0.70*	1.99	2.52
August	2.27	1.31	*6.57*	3.38	2.95
September	1.24	2.15	3.80	2.40	2.44
October	*0.60*	*0.89*	1.30	0.93	1.72
Total May to October	17.70	16.94	18.85	17.83	17.25
Yearly Total	22.08	30.57	29.55	27.40	25.71
Planting Site— May 24th to September 17th	13.39	11.30	11.25		
MEAN TEMPERATURE: °F.					
May	45.8	44.1	42.3	44.1	44.8
June	50.6	49.2	48.9	49.5	50.5
July	56.2	56.4	55.8	56.1	57.5
August	54.7	57.4	52.8	54.9	55.3
September	52.0	49.3	46.3	49.2	48.9
October	47.0	46.2	38.1	43.7	40.7
Mean, May to October	51.0	50.4	47.4	49.5	49.6
Yearly Mean	38.3	38.9	35.1	37.6	36.6

Periodicity of root growth was superficially investigated by Crossley (1956) as a part of this study. His observations substantiate the belief held by many investigators that root growth is most active during periods when aerial growth is inactive. Recent greenhouse investigations of root growth of transplanted ponderosa pine (*Pinus ponderosa* Laws.) in California by Stone and Schubert (1959b) confirmed a distinct seasonal periodicity. Root initiation was observed only in the spring while root elongation was observed both in the spring and the fall; mid-summer transplants generally exhibited neither initiation nor elongation. The greatest root activity occurred in the spring immediately before flushing. It was also noted that root regeneration can occur at a lower soil temperature in the spring than in the fall.

The advantages of spring planting, indicated by root growth studies and the pattern of precipitation in this region, are demonstrated by the results of this study. The relatively poor results of fall planting may reflect the low September and October precipitation as well as reduced ability to regenerate roots at this season.

In the initial report on this project Crossley (1956) suggested an interesting hypothesis to explain the marked reduction and variation in height growth of trees subsequent to planting. The following are excerpts from the paper.

"The growth of shoots is dictated by the organ primordia laid down the previous year in the bud, modified by the rate of recovery from root damage at the time of lifting. The characteristics of these primordia depend upon conditions that existed at the time they were laid down, and the growth pattern therefore behaves in many ways along predictable lines that may have little to do with the date of planting *per se.*"

Crossley then considered the original plantation set out in 1952 and developed the following rationale.

1. "The spring transplants, set out early enough to take full advantage of the favourable season, would lay down adequate primordia in their buds and grow comparatively well the following year regardless of the nature of the 1953 growing season. Because of favourable growth and adequate climatic conditions they would lay down satisfactory primordia in their buds in the fall of 1953, and consequently their growth the following spring would be adequate, again assuming a favourable growing season. Given further favourable seasons these transplants should steadily improve in height growth until they reach the growth rate they arrived at in the nursery prior to lifting.

2. The midsummer transplants would grow comparatively poorly the year following, regardless of the season, since the struggle to establish themselves during the first season would likely have an adverse effect upon the primordia of buds laid down in the year of planting. Once having done poorly it will be a slow gradual process to recovery, and several years can be expected to elapse before height growth is no longer depressed.

3. The fall transplants could be expected to grow comparatively well the following season, due to the fact that they were lifted from the nursery after the buds were formed, and their terminal growth would therefore attempt to express the excellent growing conditions experienced the previous year in the nursery."

Carrying growth predictions into the third year Crossley stated: ". . . the spring transplants could be expected to improve in average height growth over the previous year's results but still not regain their original rate of growth. They have had two full seasons to recover and to adjust to the new environment. The mid-summer transplants should behave in the same manner since they have had one full season to recover and to adjust to the new environment. The fall transplants have just experienced their first growing season in the new environment, and during that season the primordial buds formed were the result of the shock of transplanting and the changed environment. Terminal growth of the fall transplants could therefore be expected to be poor during the second season, with a gradual increase to normal with the passage of the years."

In the foregoing hypothesis the shock of planting and the changed environment are presumed to have little effect on primordia formation of spring transplants but a pronounced effect on primordia formation of fall transplants. It would be more logical to expect similar effects and, if growth after planting is dependent largely on primordia formation, similar patterns of growth after spring and fall planting.

In order to test Crossley's hypothesis annual height growth to 1959 was computed, by physiological season of planting, for all plantations.

Height growth of the 1952 plantations conformed fairly well to the hypothesis. Unfortunately however, as a result of winter injury to many of the trees in 1955, the 1955 terminal growth did not increase as greatly as might otherwise have been the case.

In the 1953 plantation, spring-planted stock showed depressed growth in 1954 and 1955, summer-planted stock showed depressed growth from 1953 to 1955 and fall-planted stock behaved as predicted. However, the growth pattern of the 1954 plantations was erratic and did not conform to Crossley's hypothesis.

These results suggest that the pattern of growth after planting cannot be predicted solely on the basis of primordia formation of the previous year. Climatic conditions during and after planting and the physiological condition of the stock at the time of planting are also important factors.

In this experiment the transplant beds and the planting site were only a short distance apart. This minimized the risks involved in the transport of stock lifted during the period of active aerial growth. In practice a considerable time lapse may occur between lifting and planting. Placing of transplant beds close to the planting area would be of value, or spring-lifted stock could be "heeled in" at the planting site until needed (Stone and Schubert, 1959a). It is also possible to hold and transport spring-lifted stock in cold storage (Baldwin 1952, Bjorkman 1956, Deffenbacher and Wright 1954, Stoeckeler 1950, Stone and Schubert 1959a). The feasibility of delayed planting of dormant stock in this region is questionable, however, and would require careful investigation.

SUMMARY AND CONCLUSIONS

In 1952 a study was initiated on the Kananaskis Forest Experiment Station to investigate the possibility of continuous planting of white spruce throughout the frost-free period. Plantings were undertaken weekly from May to October inclusive in 1952, 1953, and 1954. Mortality and height growth were measured each year up to and including 1959.

The conclusions follow:

1. Mortality has been acceptable to date regardless of the month of planting. This indicates that the continuous planting of white spruce throughout the frost-free period on comparatively dry sites in the Subalpine Region of Alberta is feasible, at least during years of near normal precipitation.
2. The effect of month of planting on mortality and height growth varied from year to year, depending on weather and soil moisture conditions prevailing during the period of establishment. However, all significant differences between individual months favoured earlier planting.
3. Averaging values for all years, mortality increased and height growth decreased progressively with deferment of the planting date from May through to October.
4. The effect of month of planting on current height growth was still evident in the fifth year after planting.

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Appendix I: Mortality

Analyses of Variance—Total Mortality Five Years After Planting

Source of Var.	D. of F.	Mean Square			F. Ratio		
		1952	1953	1954	1952	1953	1954
Rows	5	3.29	156.67	53.58	1.03	8.03*	4.34*
Columns	5	15.36	51.78	60.44	4.83*	2.66	4.47*
Planting Month	5	10.83	118.24	304.11	3.41*	6.06*	22.51*
Error	20	3.18	19.50	13.51			
Total	35						

Test of Differences Between Months of Planting

	1952	1953	1954
May vs. June	−0.67	− 6.33	+ 0.17
May vs. July	0.83	− 3.83	− 8.50*
May vs. Aug.	−1.33	−12.66*	− 2.67
May vs. Sept.	−1.67	− 9.83*	− 9.33*
May vs. Oct.	−3.00	− 6.66	−18.33*
June vs. July	1.50	+ 2.50	− 8.67*
June vs. Aug.	−0.66	− 6.33	− 2.84
June vs. Sept.	−1.00	− 3.50	− 9.50*
June vs. Oct.	−2.33	− 0.33	−18.50*
July vs. Aug.	−2.16	− 8.83*	+ 5.83
July vs. Sept.	−2.50	− 6.00	− 0.83
July vs. Oct.	−3.83*	− 2.33	− 9.83*
Aug. vs. Sept.	−0.34	+ 2.83	− 6.66
Aug. vs. Oct.	−1.67	+ 6.00	−15.66*
Sept. vs. Oct.	−1.33	+ 3.17	− 9.00*

* Sig. at 5% level.

Appendix II: Height-Growth

Analyses of Variance—Total Height Growth Five Years After Planting

Source of Var.	D. of F.	Mean Square			F. Ratio		
		1952	1953	1954	1952	1953	1954
Rows	5	2.55	8.46	4.07	1.02	4.05*	< 1
Columns	5	19.40	2.76	19.69	7.73*	1.32	4.77*
Planting Month	5	22.79	25.32	23.97	9.08*	12.11*	5.80*
Error	20	2.51	2.09	4.13			
Total	35						

Test of Differences Between Months of Planting

	1952	1953	1954
May vs. June	−0.10	3.85*	−2.96
May vs. July	1.71	3.75*	0.37
May vs. August	3.71*	4.56*	2.19
May vs. September	3.45*	4.68*	2.30
May vs. October	4.38*	6.10*	1.80
June vs. July	1.81	−0.10	3.33
June vs. August	3.81*	0.71	5.15*
June vs. September	3.55*	0.83	5.26*
June vs. October	4.45*	2.25	4.76*
July vs. August	2.00	0.81	1.82
July vs. September	1.74	0.93	1.93
July vs. October	2.67	2.35	1.43
August vs. September	−0.26	0.12	0.11
August vs. October	0.67	1.54	−0.39
September vs. October	0.93	1.42	−0.50

* Sig. at 5% level.