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THE POSSIBILITY OF CONTINUOUS PLANTING OF WHITE SPRUCE THROUGHOUT THE FROST-FREE PERIOD

by

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CONTENTS

64827—1½

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Project K.67

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INTRODUCTION

It has generally been thought that the best time for planting out forest nursery stock is during the dormant season, with early spring as the best and most usual time. Such a planting period decrees that the newly planted tree will have only a short time to wait before root growth commences and moisture and nutrients can be obtained. It is customary to discontinue planting as soon as aerial growth becomes active, on the grounds that such activity sets up an immediate demand for moisture and nutrients that the damaged and yet unestablished rootlets are not able to satisfy. Such restrictions result in a very short spring planting season.

Operations are often lengthened by planting in the late fall of the year when the plants are again recognized as dormant, but critics of this period emphasize the danger of loss by frost-heaving before the roots have had a chance to firmly anchor the plant. Hawley (1949) lists as one disadvantage of fall planting "that the tree must wait a relatively long time before its roots start to grow". Other investigators, however, appear to be well satisfied that the tree root grows in early spring and in the late fall, and is more or less dormant during the intervening summer period when aerial growth is active.

Stephens (1931), in a study of root growth of white pine, relates root activity to the supply of oxygen and carbon dioxide in the soil. He states that oxygen is abundant in the spring and fall and carbon dioxide in mid-summer. Anderson (1934) notes that slowing down in root growth corresponds with the tree's period of highest transpiration. He suggests that this results in an increased suction tension on the root cells and consequently a low turgor pressure, and the lower the turgor pressure in the root cells the slower the rate of growth. Kinman (1932), studying forest trees, notes that the greatest seasonal activity of roots preceded the critical period of need for moisture and nutrients during fruit setting, and Heinricke (1935) found that the root growth of apple trees is relatively rapid during several weeks prior to leaf fall and considers that such action is necessary to increase the absorption of nutrients for use the following spring. Kienholz (1934) suggests an interval control of the rhythm of growth of roots, leader and cambium.

On the other hand, Kramer (1949) doubts any inherent periodicity in root growth. He suggests that temperature is the main control factor when adequate moisture is present, and such a hypothesis is supported by Kaufman's (1945) jack pine root growth investigations. He found that in Minnesota root growth extended from April to October, commencing when the surface six inches of soil had reached a temperature of 40°F., although growth was slow until it reached 50°F. Growth slowed down when the level of available moisture fell to less than

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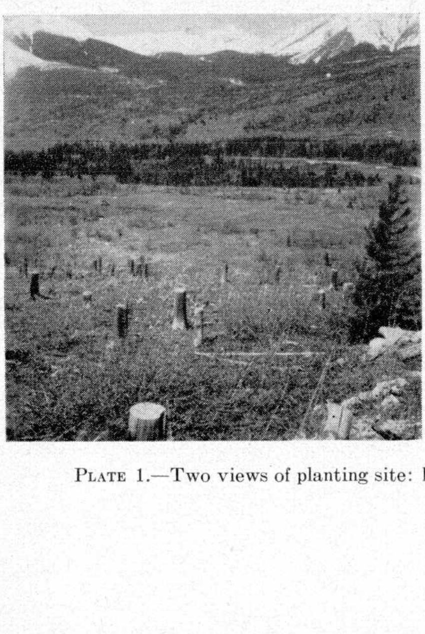
four per cent and the rate of evaporation was high, or when the temperature dropped over any appreciable length of time. He reports that root and leader growth began within a week of one another in the spring but that leader growth was nearly over by the end of July, while root growth usually continued into October.

Such conclusions are not incompatible with Kienholz's rhythm of growth. During his study of growth of conifers he noted a great surge of growth of roots, leader, and cambium early in June. After this initial surge, needles reached their maximum growth rate, and this was followed by a second maximum in cambial growth. Roots reached a second maximum growth after a full complement of needles was functioning and cambial growth was nearly completed.

Whatever the cause and whatever the periodicity of root growth, it is at least apparent from previous studies that root activity does not necessarily coincide with the growing period of the aerial parts of the tree. Considerable damage is done to the roots of a tree during the lifting operation in the nursery. If rapid root repair is the main criterion of success after planting has been completed, the suggestion is therefore inescapable that the planting season should coincide with the season or seasons during which this can best be effected. The purpose of this study was to investigate the feasibility of broadening the planting season to include all the periods when root growth is active.

METHODS

The study was undertaken on the Kananaskis Forest Experiment Station, (51° 00′N, 115° 10′W) which is located at an elevation of 4,500 to 5,000 feet in the subalpine forest region in Alberta. Plans were made to field-plant white spruce *(Picea glauca* (Moench) Voss var. *albertiana* (S. Brown) Sarg.) from the transplant beds in the Station nursery once a week during the entire season from the time the frost left the ground in the spring until it re-entered again in the fall. The planting site selected for the study was on an old burned-over flood plain bordering the Kananaskis River. The soil is an immature alluvium, sandy loam in texture with some contained rock. At an approximate depth of two feet the surface deposit changes abruptly to a coarse gravelly and cobbly outwash. In spite of the bottom-land location, drainage is rather excessive. The physiographic site can be classified as 2:1:3/0, i.e., the local climate is



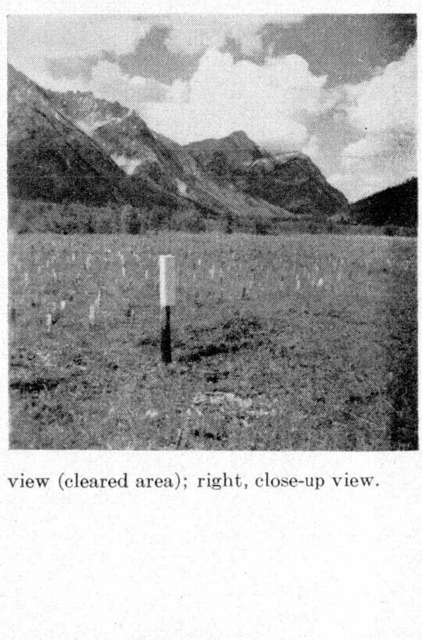


PLATE 1.—Two views of planting site: left, distant view (cleared area); right, close-up view.

warm-moist, the soil moisture regime somewhat dry, and the material permeability moderately rapid at the surface to extremely rapid below. The site is not therefore of the best.

There had been little coniferous reproduction on this area during the 15 years following the 1936 fire. The sparse growth present was composed almost entirely of shrubby specimens of poplar and willow. A few of these had to be removed from the planting site, and the roots were also removed in order to prevent the possibility of future sprouting. The only other planting site preparation involved the removal of the odd old stump and down-log in order to eliminate any avoidable variation in micro-climate.

In order to eliminate the effects of fertility trends on the planting results, a 6 by 6 latin square design was adopted, with 4 weeks planting in each cell. In each cell, 8 rows of 7 trees each were planted, 2 rows (or 14 trees) per week, making a total of 56 trees per cell at the end of 4 weeks. Since each week's planting was undertaken in each of the 6 cells, a total of 84 trees per week were set out. Planting took place over a 24-week period, so that a total of 2,016 trees were set out each season.

It should be noted that each cell contained 4 weeks' planting. Unfortunately, this is not a month, but for purposes of easy reference it is so referred to. Such gradual accretion of time throughout the season results in the magnification of the error, so that the plantings referred to as "October" may actually mean those set out in the last half of September and the first half of October.

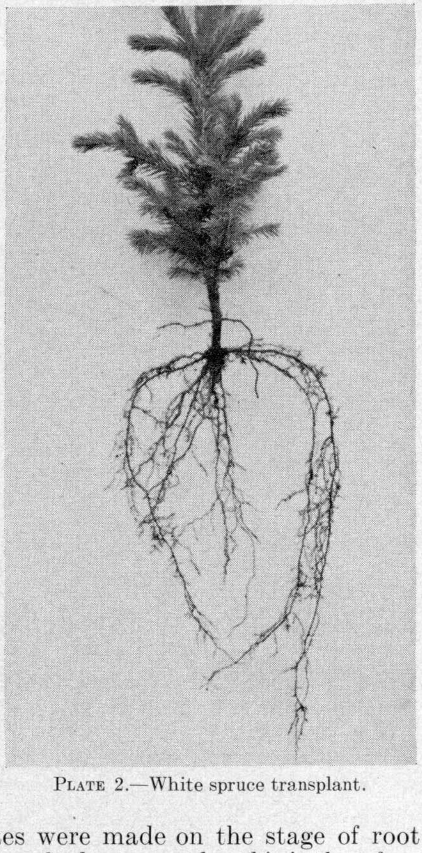


Plate 2.—White spruce transplant.

In an attempt to obtain information on the effect of the climatic factor, the study was replicated by years. The first plantation was set out in 1952, the first replicate in 1953, and the second and final replicate in 1954. The same planting site was used throughout, with each replicate bordering the last. There is no change in site and the experimental design is identical in all cases.

The planting stock used in 1952 was 3-3. Grown at an elevation of 4,500 feet, this stock was not excessively large (Plate 2), and at the time of lifting from the transplant beds, each week's trees were graded in order to eliminate those specimens that were exceptionally large or small. At this time five average specimens were chosen and detailed information gathered on their size and weight, and notes were made on the stage of root activity. In 1953 and 1954 stock from the same beds was used and it is therefore classified as 3-4, and 3-5. When selecting stock from the transplant beds a deliberate attempt was made to grade so that each year's supply was similar in size to that of the previous year. The success of such an attempt can be assessed from Table 1 which was prepared from samples taken from each week's planting stock.

TABLE 1.—PLANTING STOCK SUMMARY

(sample—5 transplants per week)

—	G.L.* Diam.	Top Length	Root Length	T/R	Green Top Wt.	Green Root Wt.	T/R
					(grams)	(grams)	
1952	0·30″	9·7″	11·8″	0·82	28·68	7·96	3·60
1953	0·29″	10·2″	11·9″	0·85	25·00	9·00	2·77
1954	0·33″	11·1″	13·5″	0·82	36·00	11·00	3·21

*Ground line.

ROOTING ACTIVITY

Several attempts were made throughout the three seasons to establish a pattern of root growth. These included simple weekly observations of root activity in the nursery stock, as well as an attempt to accurately measure the weekly growth of selected roots on sample trees.

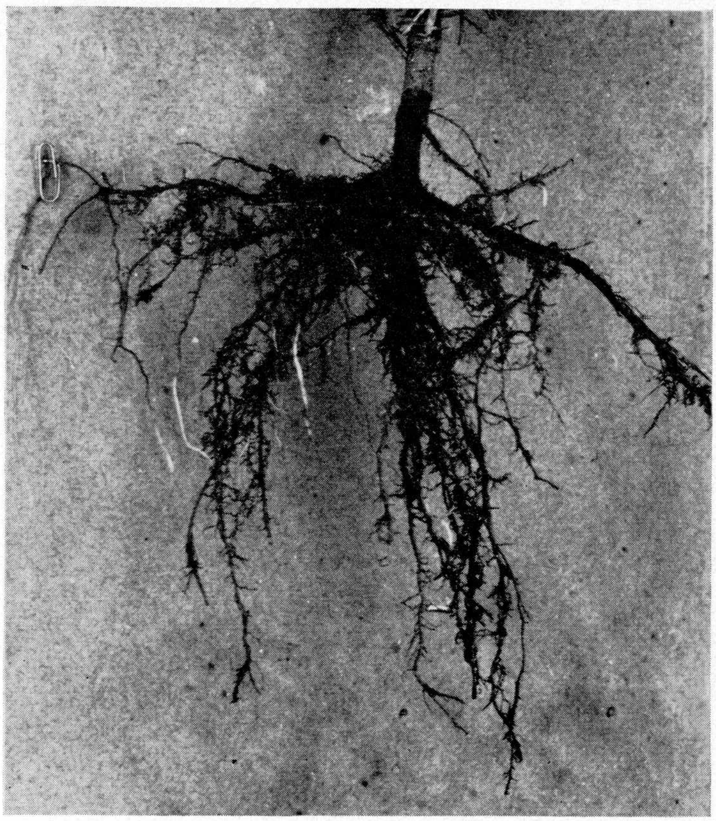


PLATE 3.—Root activity illustrated by elongated white root tips.

From the weekly observations, comparisons were obtained which illustrate the rhythm of root activity. These are presented in Figures 1, 2 and 3.

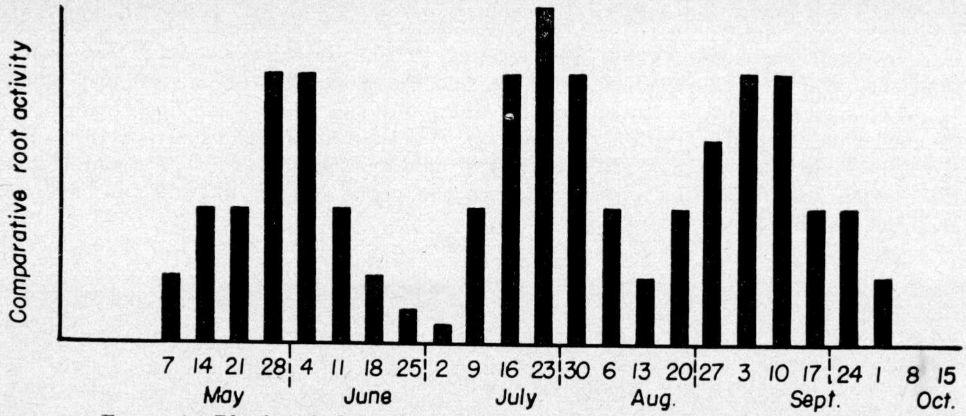


FIGURE 1.—Rhythm of white spruce root activity estimated during the 1952 season.

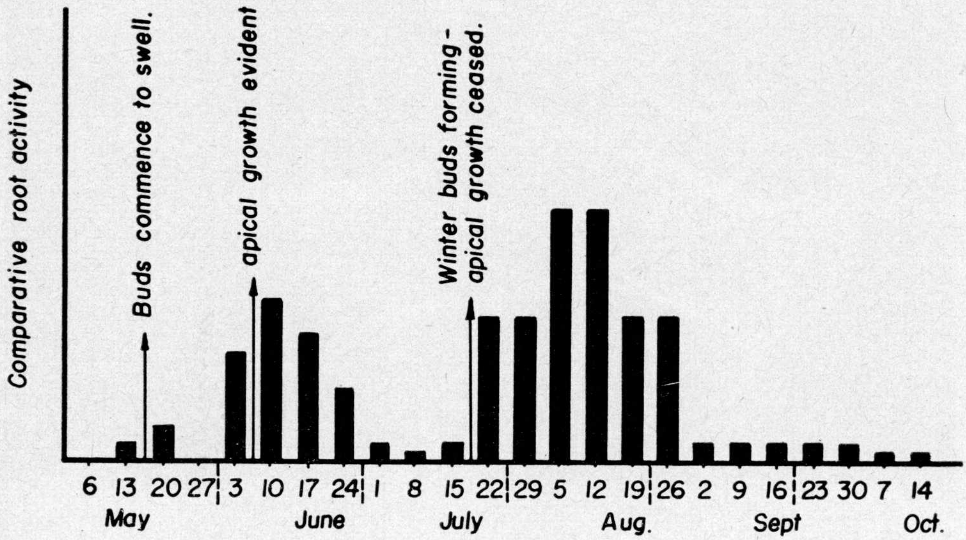


FIGURE 2.—Rhythm of white spruce root activity estimated during the 1953 season.

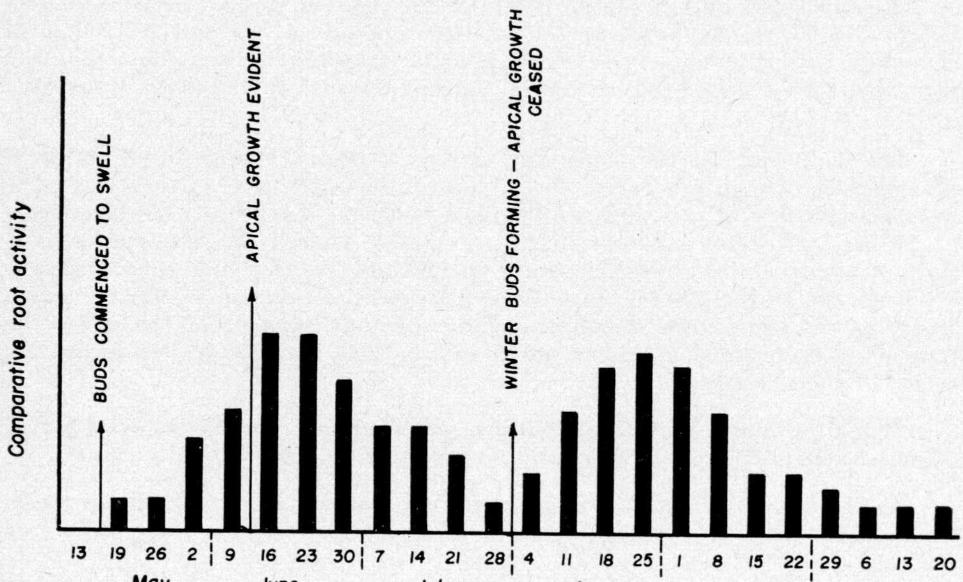


FIGURE 3.—Rhythm of white spruce root activity estimated during the 1954 season.

In addition to the weekly observations of root activity amongst the transplant stock in the nursery, an attempt was made during the second and third years to gather more accurate data by observing the roots of a selected number of individual trees throughout the season. This involved the construction of a trough whose glass-walled sides sloped in toward the base. The trough was filled with soil from the nursery and in the early spring of 1953 four spruce transplants (3-4 stock) were planted in it.

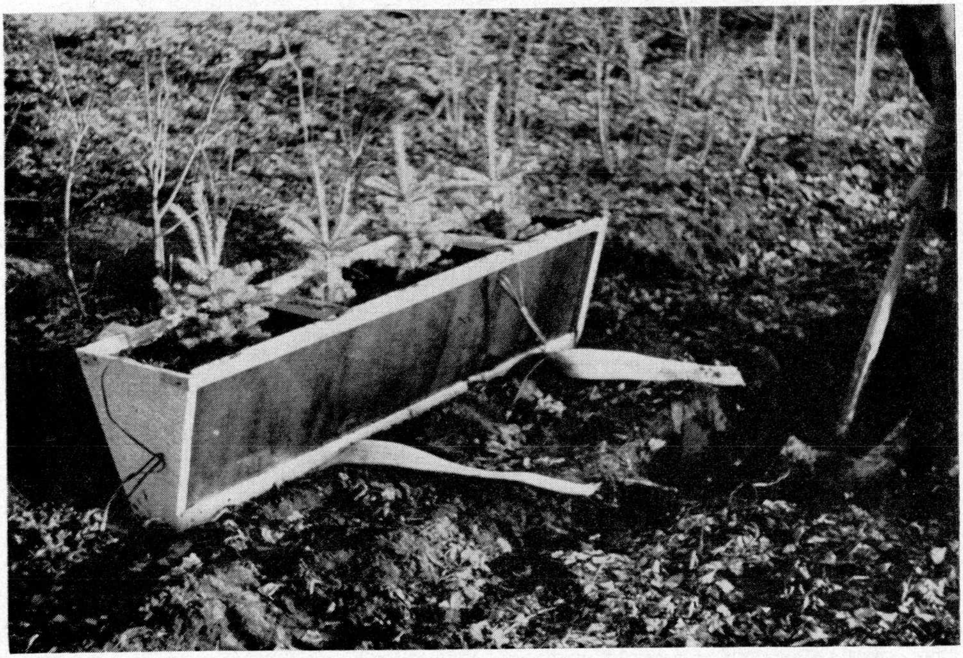


PLATE 4.—Glass-sided trough with white spruce transplants.

A trench was dug in the nursery and the planted trough, fitted with two heavy straps fastened underneath, was lowered into it so that its soil level coincided with the nursery level. No artificial watering was done and the transplants grew under the same conditions as those in the adjacent transplant beds.

Once a week, on the same day as the transplants were lifted for field planting, the trough was raised on to trestles, the outer faces of the glass walls were washed free of dirt and observations made on the growth of those roots appearing against the inner surface of the glass. During the first season roots did not appear on these surfaces until July 22nd. At this time their positions were marked on the outer surface of the glass with a stylus and each succeeding week, as the roots grew downward along the inner surface of the glass, the position of each growing tip was noted and marked, and the growth measured, recorded and averaged.

If Figures 2 and 4 are compared it is apparent that, for the common period of measurement, there is a very similar rhythm of root growth.

In the late fall the glass trough was lifted and new glass sides slipped in to replace those that had become defaced. The trough was then placed in a cool

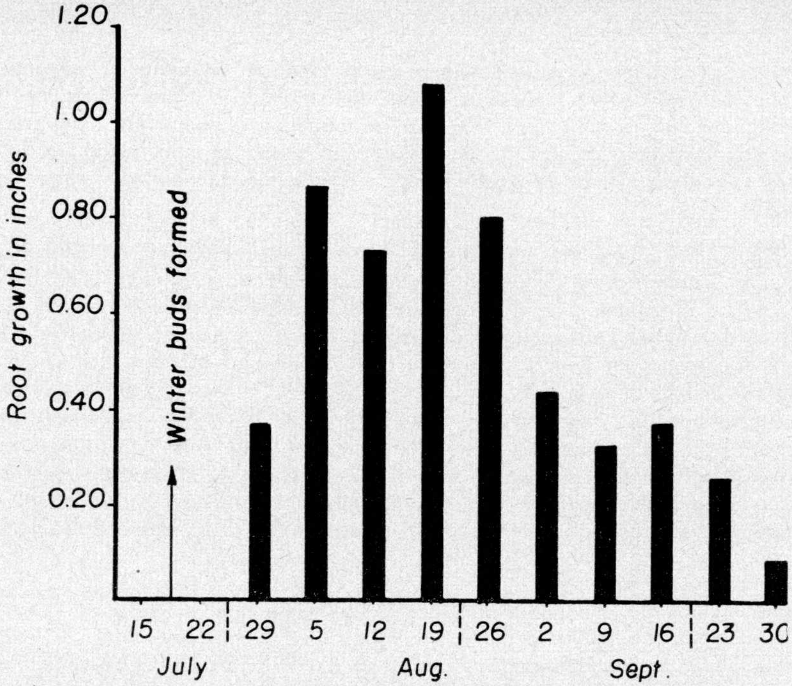


FIGURE 4.—Average weekly root growth during latter half of the 1953 season from observations made of roots growing along the inner faces of a glass-sided trough.

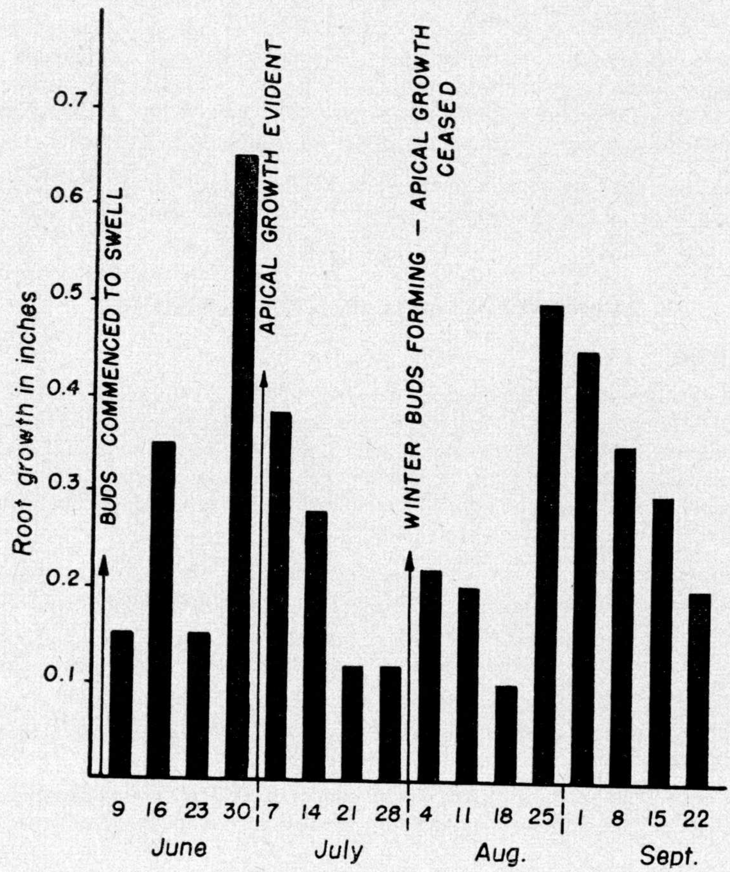


FIGURE 5.—Average weekly root growth in 1954 from observations made of roots growing along the inner faces of a glass-sided trough.

64827—2½

basement over winter. Unfortunately such storage resulted in serious drying out of the soil, and after the trough was returned to the nursery in the spring, both root and top development of the four spruce transplants appeared to be retarded for a while. It also took a short time for the root ends, damaged by changing the glass sides, to grow back to the glass face where they could be observed.

If Figures 3 and 5 are compared there is still evidence of similar growth rhythms, although Figure 5 does suggest a minor surge in root activity during the middle of the summer. It is not intended to suggest that these are accurate methods of studying root activity, but from the evidence at hand it is obvious that a periodicity does exist. Whether it is dependent upon an inherent control or upon the levels of moisture and temperature, it is not possible to say. The important fact is that root growth appeared to be reaching its maximum before the terminal elongation of the aerial parts of the plant had commenced, slowing down steadily during the period of active height growth, entering a second surge of growth after height growth had ceased, and continuing in a declining fashion until observations were discontinued with the advent of frozen soil in the late fall.

FIELD PLANTING

Field planting commenced as early as possible in the spring of each year and continued each week until the ground was frozen in the fall. A rain gauge was set out at the planting site each season and daily records were kept of precipitation (Figures 6, 7 and 8).

Fourteen transplants were set out each week in each of the six replicate blocks. Hole planting was done and in order to prevent the 3-man planting crew from taking excessive care when setting the transplants, a time limit of 84 trees per half-hour was set—or a rate of 56 trees per man-hour.

During the planting season notes were kept on the time of budding out, and at the conclusion of each season a tally was made of mortality and of height growth.

MORTALITY AND HEIGHT GROWTH

1952 Planting

The mortality data obtained at the conclusion of the first complete season and presented in Figure 9 are uniformly low and it is apparent that no significant difference exists between planting dates; therefore statistical analysis was not undertaken. By the conclusion of the second complete season (1954), mortality in some months had increased significantly, and a statistical analysis (Appendix 1) revealed the following information:

(a) The mortality of the stock set out during the month of October was highly significantly greater than the mortality of the stock set out in May, July, or September.

(b) The mortality of the stock set out in August was highly significantly greater than the mortality of the stock set out in July.

(c) The mortality of the stock set out in June was significantly greater than the mortality of the stock set out in July.

(d) There was no significant difference between the mortalities for May, July and September, nor between August, October and June.

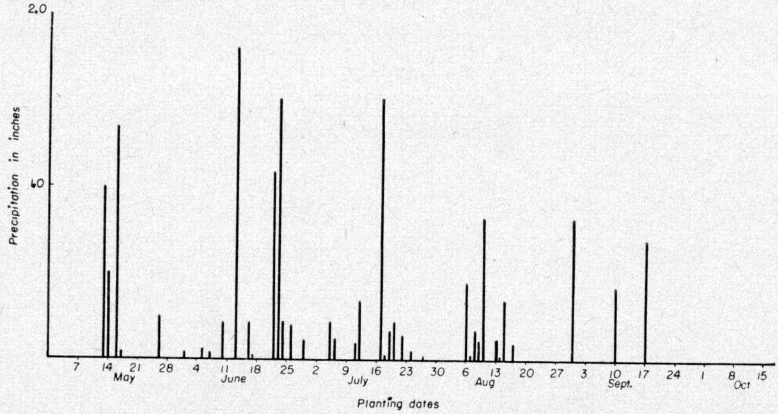


FIGURE 6.—Daily precipitation at planting site throughout the 1952 season. Total precipitation, 16·30″; local 16-year average, 14·47″.

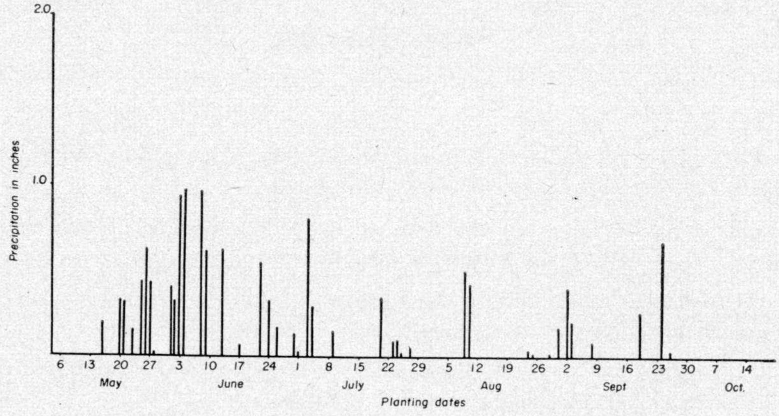


FIGURE 7.—Daily precipitation at planting site throughout the 1953 season. Total precipitation, 13·28″; local 16-year average, 14·47″.

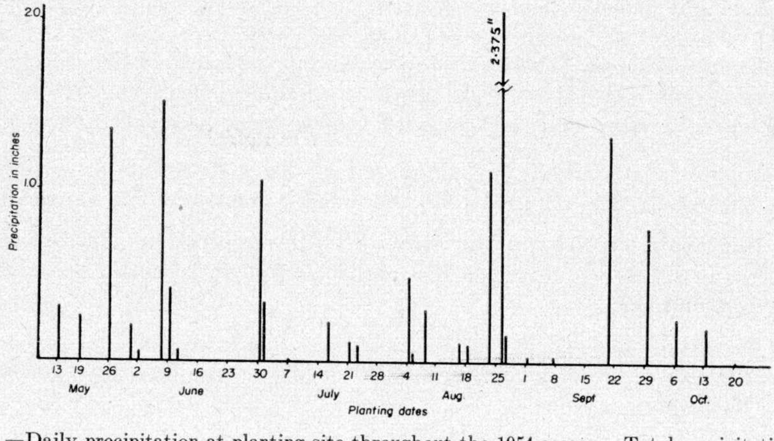


FIGURE 8.—Daily precipitation at planting site throughout the 1954 season. Total precipitation, 13·88″; local 16-year average, 14·47″.

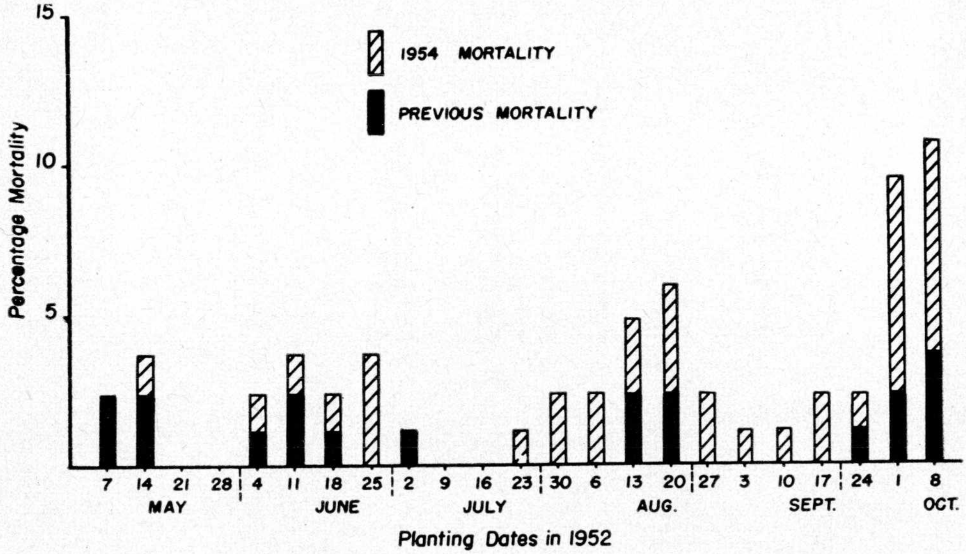


FIGURE 9.—Cumulative mortality by planting weeks in the 1952 plantation by the fall of 1954.

In addition to the collection of mortality data, the annual height growth was measured at the conclusion of each field season.

An analysis of variance on the data presented in Figure 11 was completed (Appendix 2), from which the following conclusions can be drawn:

1. the height growths in both the June and the July plantations were highly significantly poorer than on the remainder.
2. the height growth in the September plantations was significantly better than in either August or October plantations.
3. there was no difference in the height growth in the September and May plantations, nor between May and the August and October plantations.

These height growth results, together with the insignificant mortality, were very much as expected—good results in height growth of stock set out the previous year, during periods of active root growth, and poor results when stock was set out during periods of active height growth. Consequently the height growth results (Figure 12) obtained the following season came as something of a shock.

An analysis of variance was completed in order to test the significance of the data (Appendix 3). From it the following conclusions can be drawn:

1. the height growths in the May and June plantations showed no significant difference, but each was highly significantly better than the other four months.
2. the height growth in the July plantation was significantly better than August plantation growth, and highly significantly better than October.
3. there was no significance between the height growths for the August, September and October plantations.

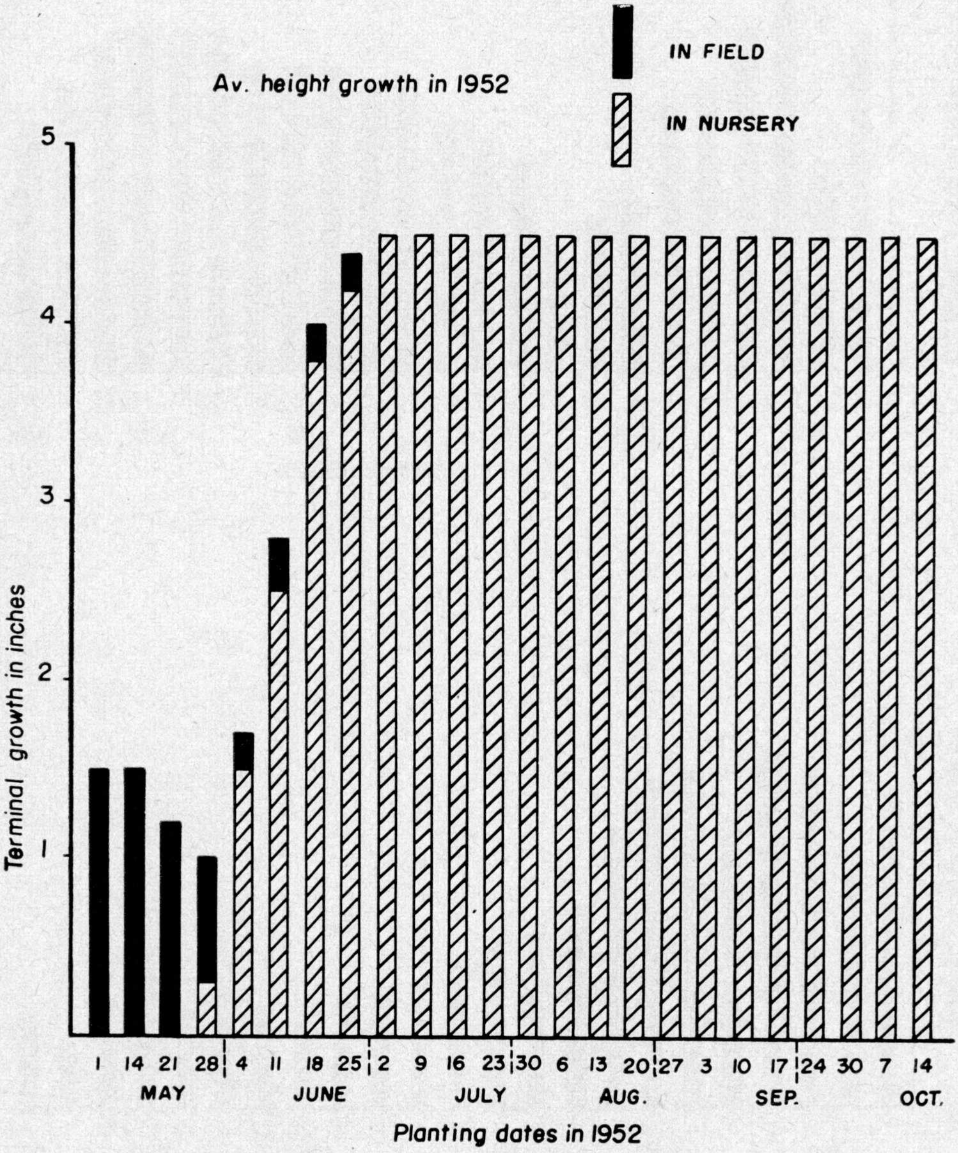


FIGURE 10.—Average height growth of the survivors of each week's planting (1952) at the conclusion of the first season (1952).

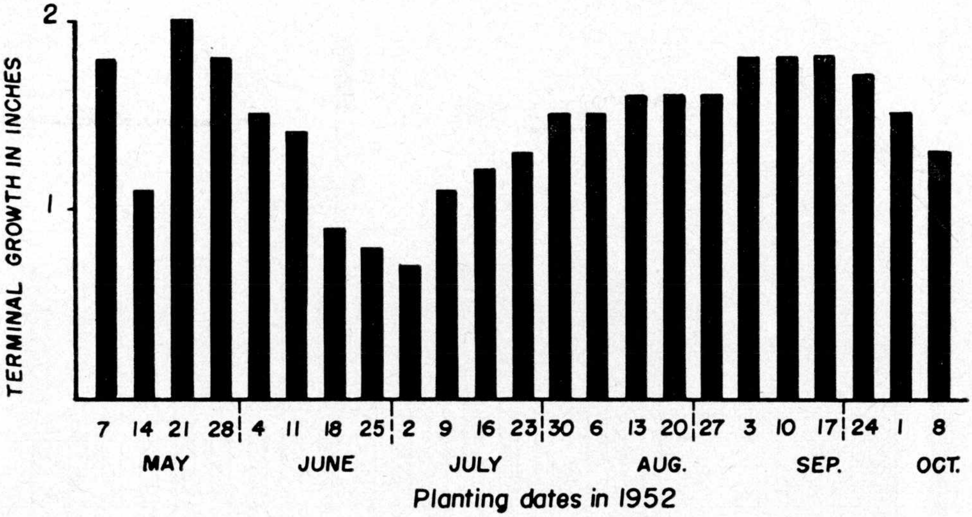


FIGURE 11.—Average height growth of the survivors of each week's planting (1952) during the second season (1953).

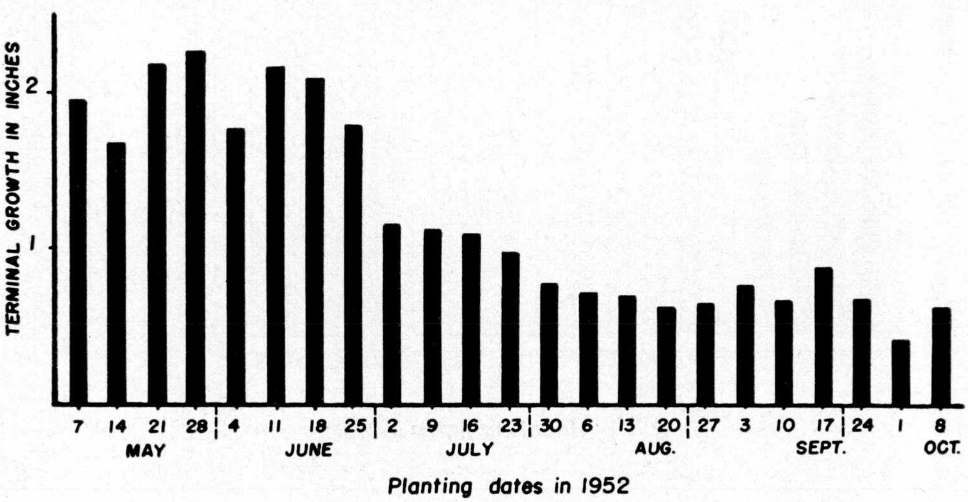


FIGURE 12.—Average height growth of the survivors of each week's planting (1952) during the third season (1954).

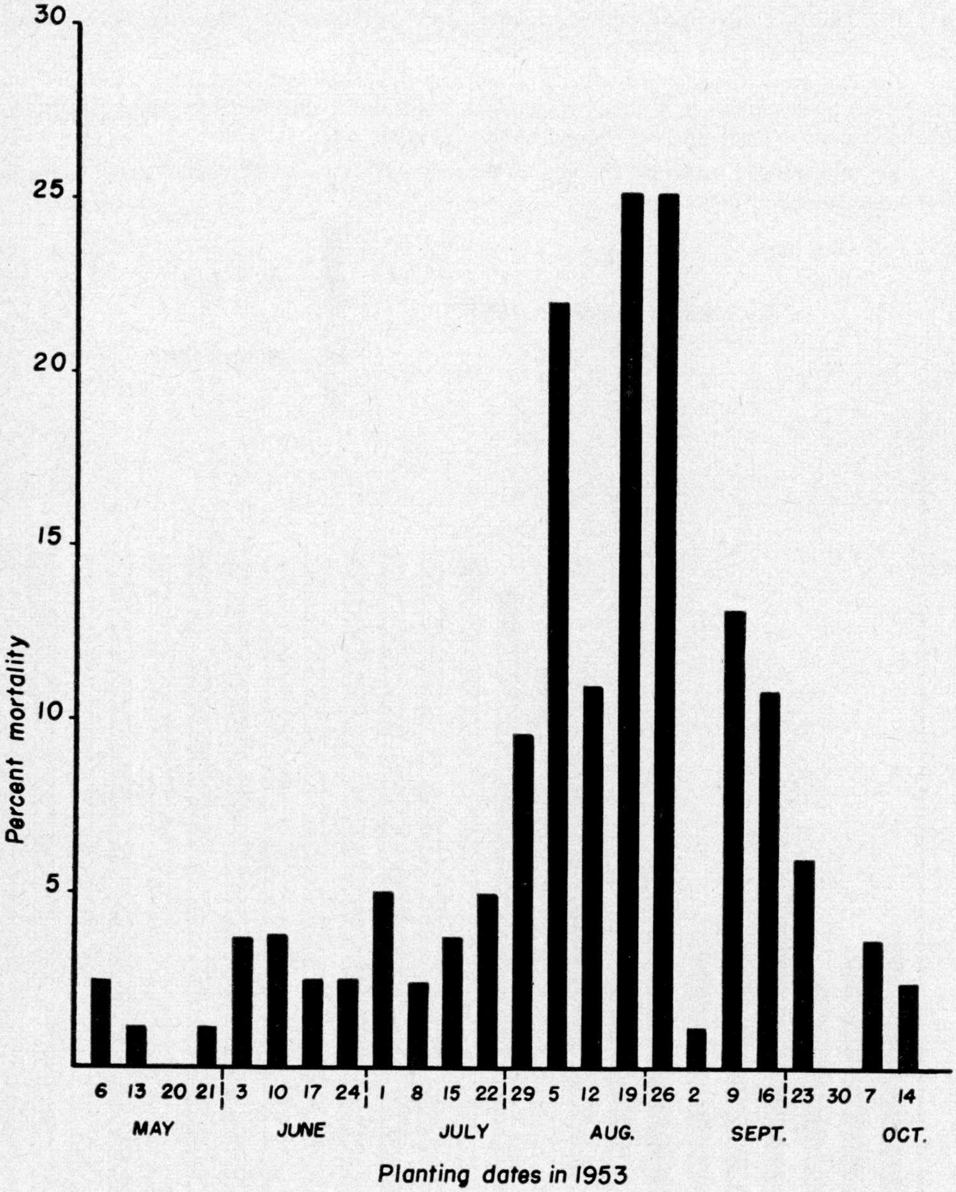


FIGURE 13.—Cumulative mortality by planting weeks in 1953 plantation by the fall of 1954.

1953 Planting

Contrary to the results obtained in the 1952 plantation, Figure 13 suggests a rather large variation in mortality in the 1953 plantation and an analysis of variance was run to test the significance (Appendix 4). The following conclusions are apparent:

1. the mortality in the August and September plantations was highly significantly greater than in any of the other four plantations.
2. there is no significance in mortality between the August and September plantations.

3. there is no significance in mortality between the plantations set out in May, June, July and October.

The average height growth data obtained at the conclusion of the second season and presented in Figure 15 exhibit a similar trend to that shown by the second year's growth of the 1952 planting (Figure 11).

Of particular interest is the depressed growth exhibited by the June plantings in both instances.

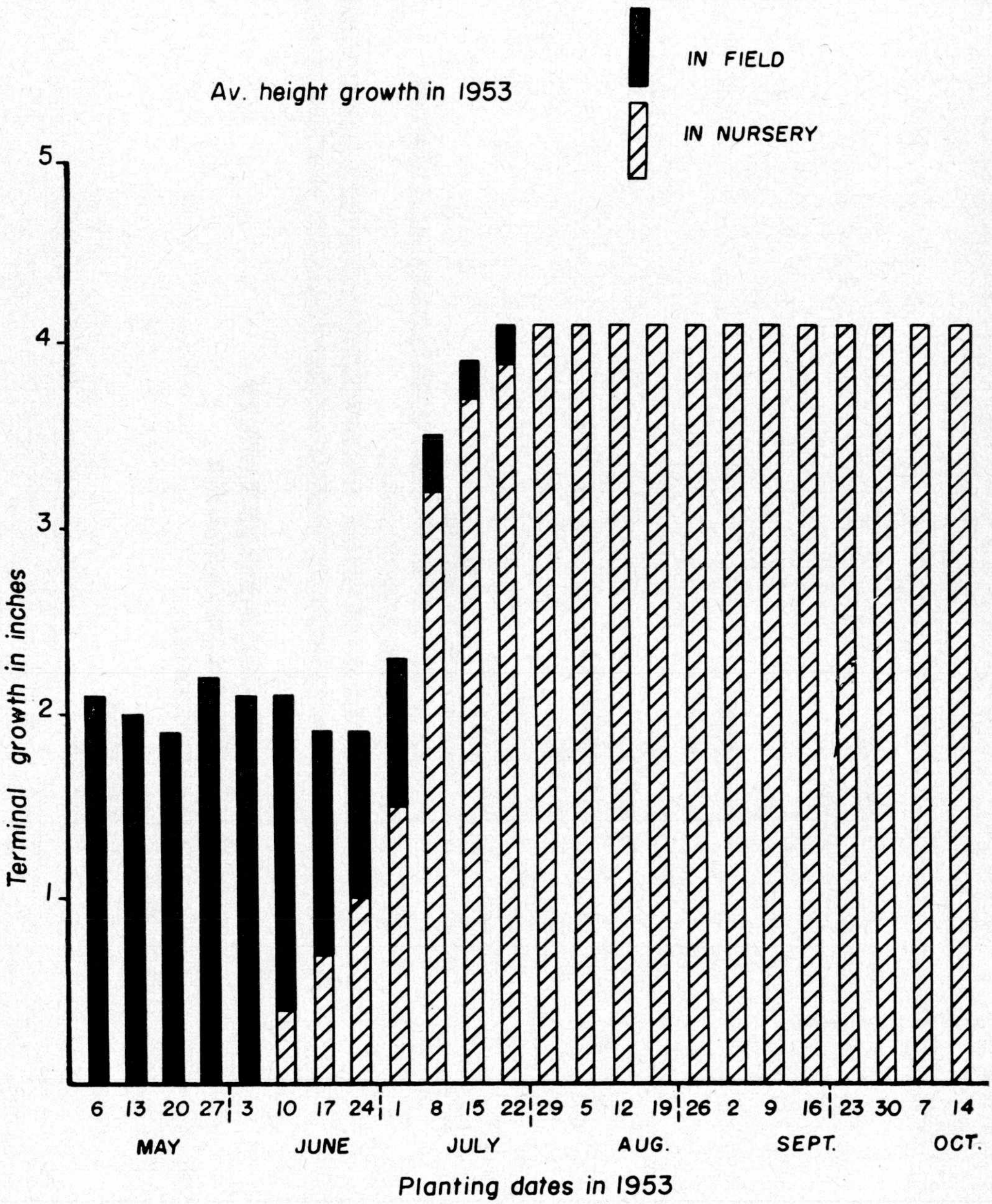


FIGURE 14.—Average height growth of the survivors of each week's planting (1953) at the conclusion of the first season (1953).

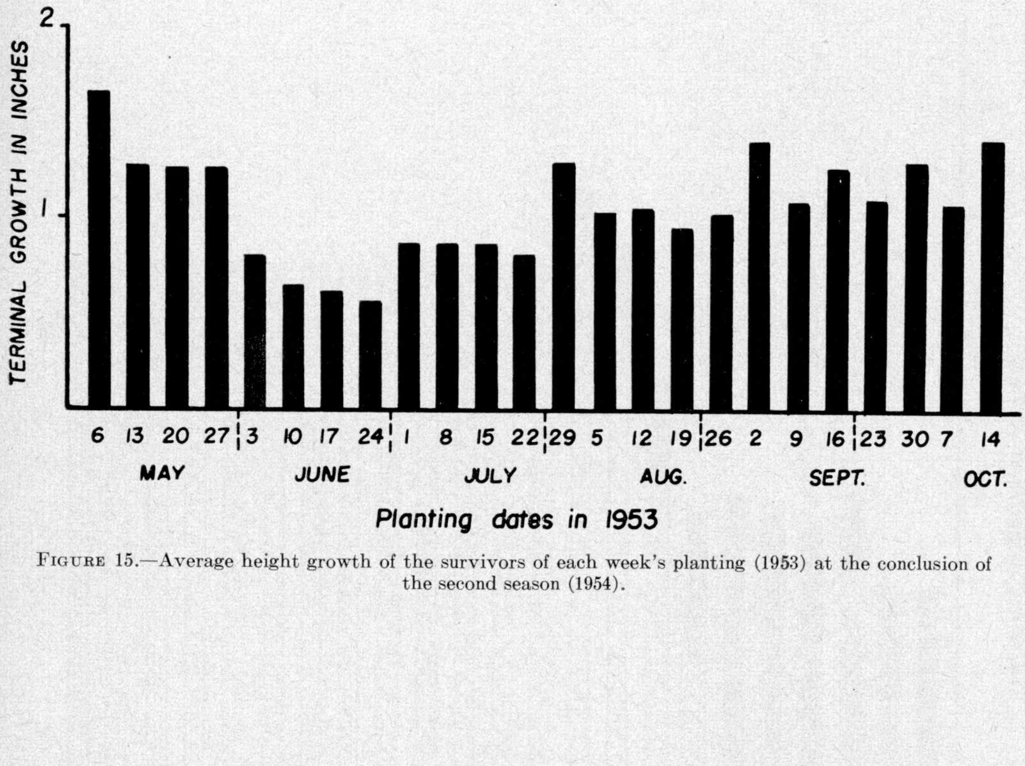


FIGURE 15.—Average height growth of the survivors of each week's planting (1953) at the conclusion of the second season (1954).

1954 Planting

Attention is drawn to the striking similarity in patterns of height growth of planting stock during the first years (Figures 10, 14 and 16). The significance will be discussed in some detail later.

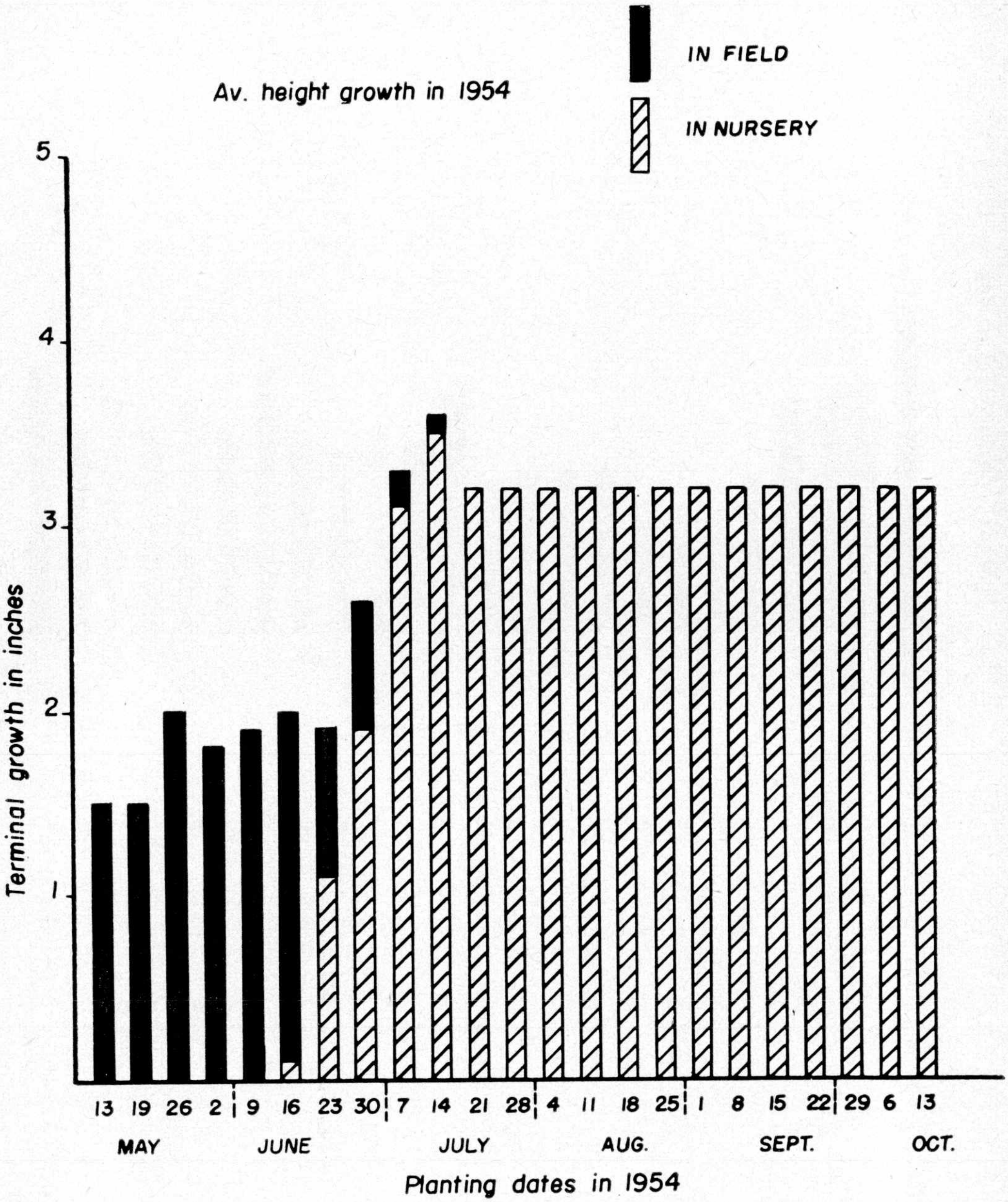


FIGURE 16.—Average height growth of the survivors of each week's planting (1954) at the conclusion of the first season (1954).

DISCUSSION AND CONCLUSIONS

From the three series of plantations set out in the years 1952, 1953 and 1954, there are two criteria of success—rate of survival, and height growth following establishment. The original premise that survival would depend on active root growth has not been established. The data at hand is not consistent since success in this respect depends so much upon the weather experienced since the plantations were set out, but the information obtained is strongly indicative of the possibility of this type of continuous planting, if rate of survival is the criterion of success. It will be recalled that the precipitation experienced during the three years of the study was about normal, and it was well distributed throughout the field season.

Visible signs of the effect of transplanting after aerial growth had commenced could be noted in the new terminal growth. For example, transplants set out on July 10th, 1953, in the second replicate, had completed most of their aerial growth in the nursery at the time of lifting. The day on which the planting was done was warm and sunny with a 10 m.p.h. wind. By the time the planting was completed most of the new growth had wilted badly and survival predictions were not favourable. However, three days later the planting site was visited, no rain had occurred in the interval, and yet most of the new growth was again erect.

While mortality has been acceptably low during the course of this study, the behaviour of height growth and general tree vigour has been disturbing. At first glance there is the suggestion that the shock of transplanting during periods in which it is supposedly difficult to transplant has manifested itself in a marked reduction and variations in height growth, and in a chlorotic appearance to the foliage and a loss of needle length. The following hypothesis is offered to account for such behaviour.

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. We will therefore attempt to predict, from the knowledge of primordial bud behaviour toward easily recognizable stimuli, the pattern of subsequent behaviour of aerial growth through the ensuing years.

Height growth data, during the first year, are of little comparative value due to the fact that in some instances growth was completed entirely in the field, in others entirely in the nursery, and in still others partly in the nursery and partly in the field. However, it is of interest to note that, in spite of adequate bud primordia resulting from growth in the nursery the previous year, the growth of transplants set out in the spring during all three years was considerably depressed (Figures 10, 14 and 16) and this is credited to the effects of root damage following lifting from the nursery beds.

Considering first the original plantation set out during the 1952 field season:

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 had 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 the 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.

Reference to Figure 11 indicates that this hypothesis agrees with the observed height growths experienced the year after transplanting in 1952 and is confirmed by the similarity in results experienced the year after planting in the 1953 plantation (Figure 15).

Carrying growth predictions into the third season, 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 midsummer 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. Unfortunately there is only one year's data on the growth during the second full season after transplanting, but reference to Figure 11 will indicate that the results support the hypothesis to date.

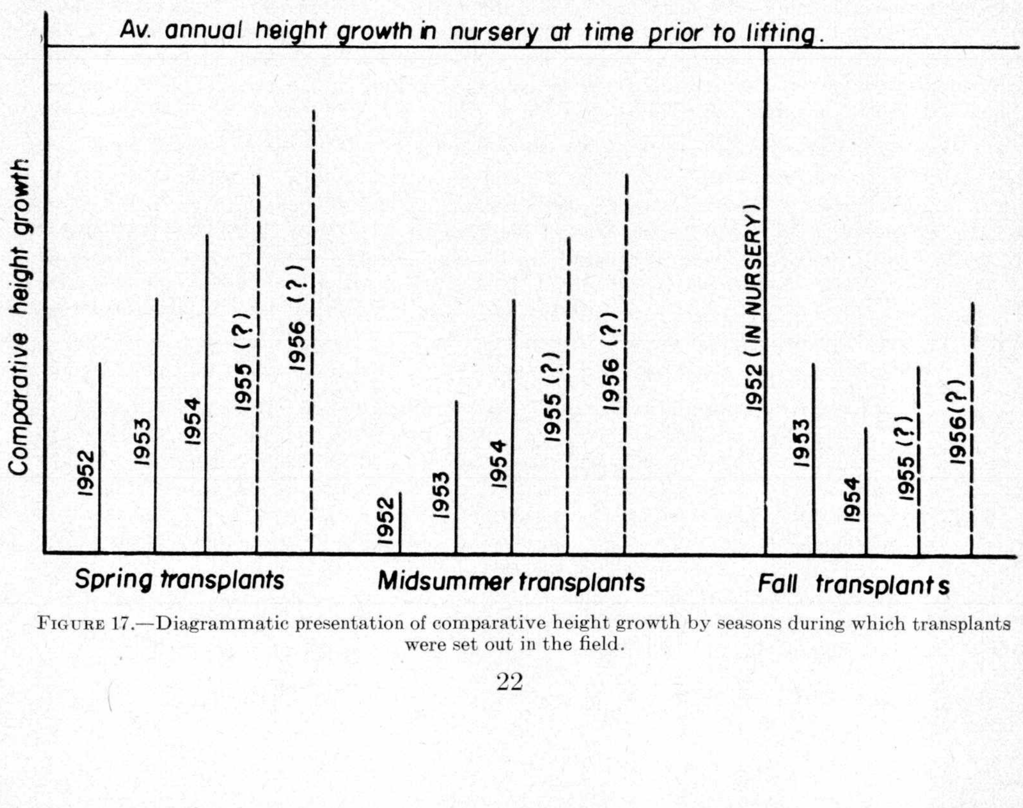


FIGURE 17.—Diagrammatic presentation of comparative height growth by seasons during which transplants were set out in the field.

The diagram presented in Figure 17 attempts to summarize the foregoing by presenting the comparative results in the first plantation set out in 1952, during the following three years. When the results are grouped by seasons during which transplanting took place, it will be seen that they fit the hypothesis fairly well. The broken lines represent estimates of future growth based on the same hypothesis. The important question now remaining to vindicate this hypothesis is—will height growth of the fall transplants start to recover in 1955?*

In order to complete the picture of the evidence at hand, the following two figures (18 and 19) are presented illustrating the initiation of aerial growth on a specified date in June by weeks of transplanting during two seasons following the setting out of the first plantation in 1952.

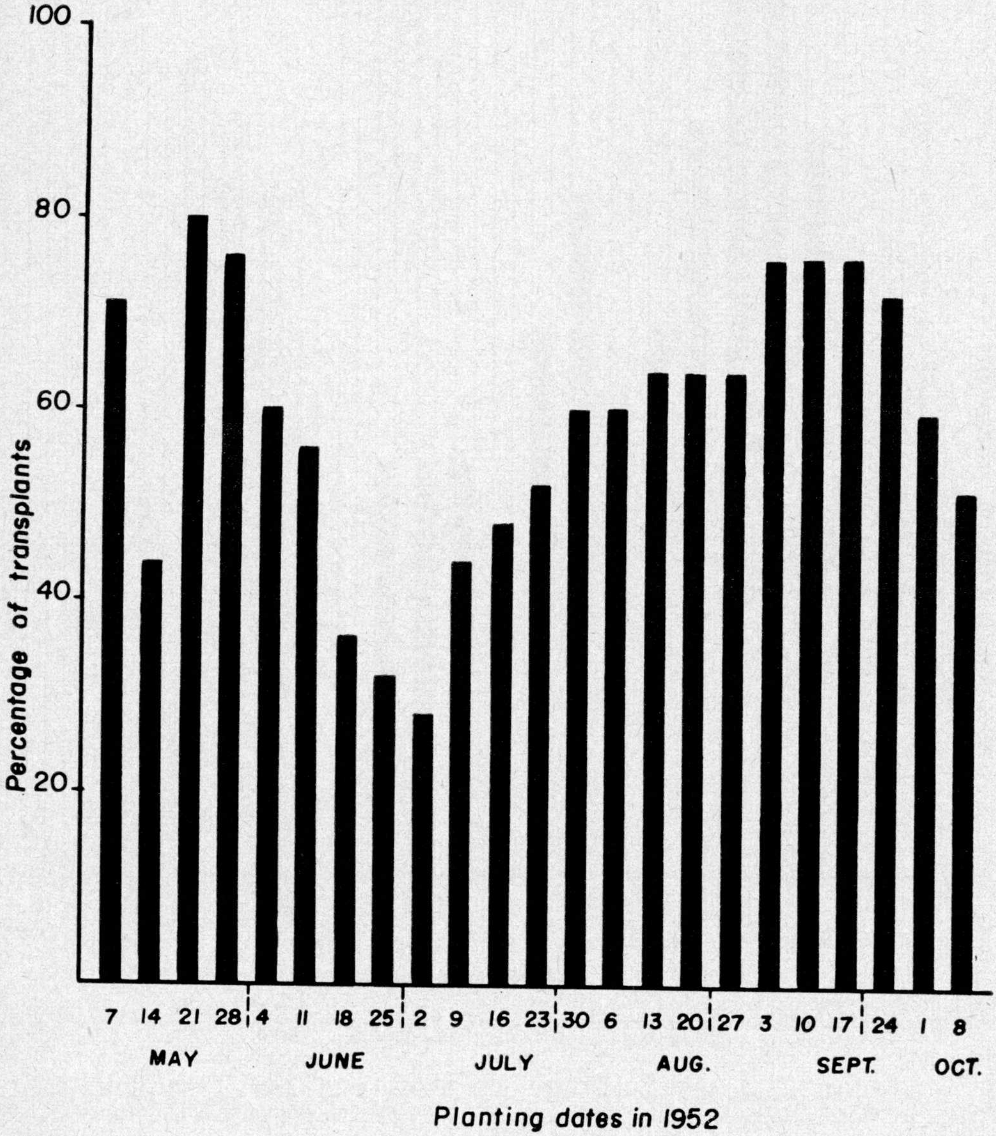


FIGURE 18.—The comparative initiation of aerial growth in 1953, in the 1952 plantation, as expressed by bud development on June 18th, 1953.

* This report was written and submitted for publication early in 1955.

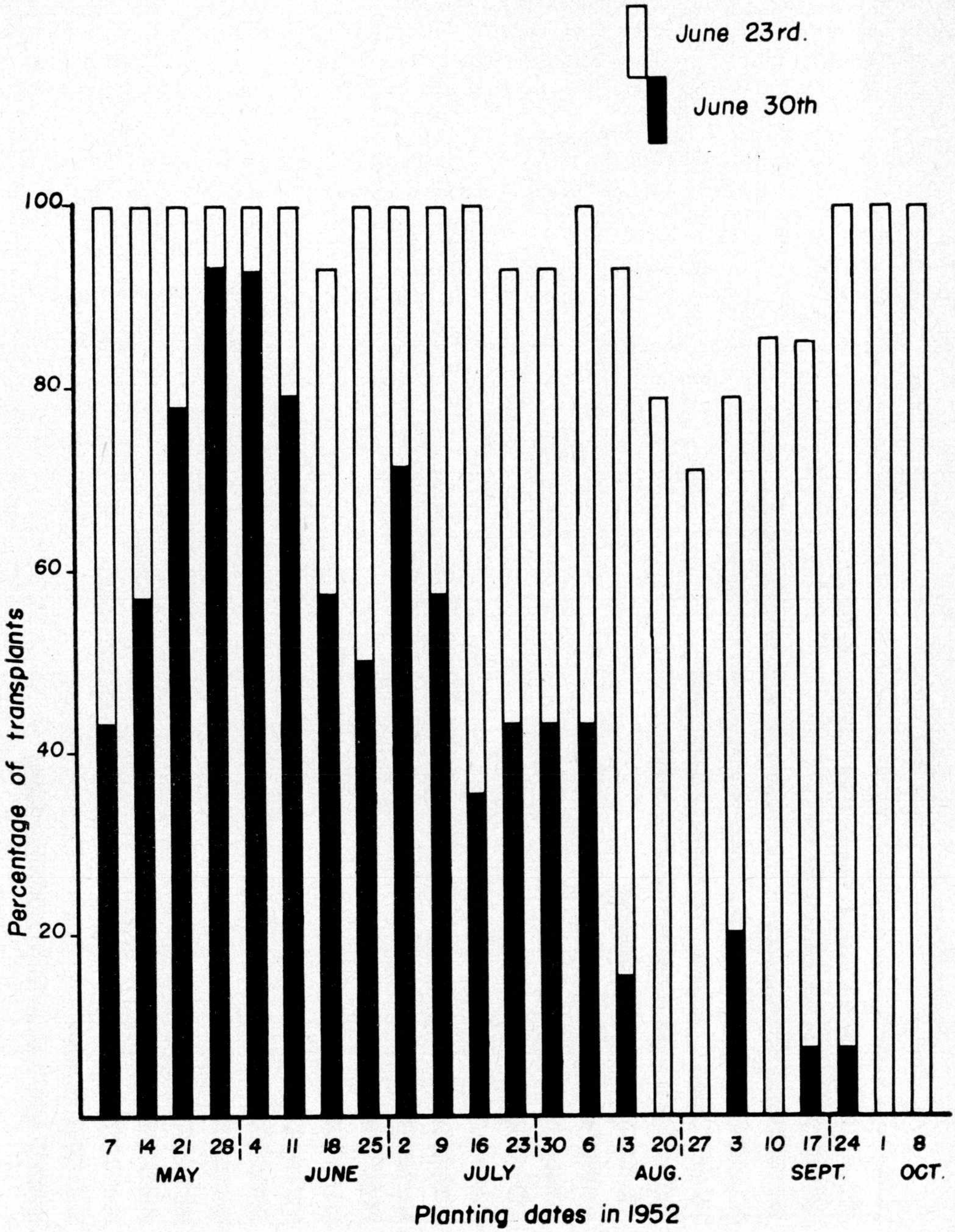


FIGURE 19.—The comparative initiation of aerial growth in 1954, in the 1952 plantation, as expressed by bud development on June 23rd and June 30th, 1954.

The 1954 season was much later than normal and therefore the June 23rd data on initiation of height growth is intended to correspond with the June 18th data of the previous season. (Figures 19 and 18.)

It will be seen that there was a considerable difference in the dates at which initial height growth commenced. This is due to the week of the year that planting was undertaken. A similar pattern in total height growth is evident. It therefore appears that the time at which height growth originates dictates the amount of height that will result during that season, and that the effect of time of transplanting on the organ primordia of that year expresses itself upon the date of budding-out rather than growth rate per se.

If it is assumed that the hypothesis presented accounts for the variations in height growth experienced, then it is a natural thing over which there is no control, and further discussion can be limited to mortality and the practical considerations involved in the adoption of a season-long planting program. As has been pointed out, at least during the normal seasons experienced, the resulting mortality has been acceptable, and it could be reduced by adopting certain precautions the need of which have become apparent during the course of this study. For example, there were odd occasions when the soil at the time of planting had become very dry and powdery and it was difficult to plant the trees firmly in it. Almost invariably the mortality rate of these trees increased, although never seriously. However, the trees planted the previous week did not appear to suffer unduly, in spite of very dry conditions the following week, suggesting that all the tree needs at the time of planting is a few days of normal conditions and it can then withstand adversity. That these few days following planting are critical is brought out by an example of the effect of frost on growing transplants. On June 7th, 1952, the planting site experienced some snow and a light frost, the intensity of which is not known. The transplants set out on June 4th, three days previously, were affected by the current terminal leader and laterals becoming flaccid, turning brown and eventually dying. Recovery in the form of new shoots was rapid.

The important fact is that the frost affected only the latest transplants. Those set out a week previously, on May 28th, were touched only lightly and those prior to that date not at all. None of the transplants affected by the spring frost showed any subsequent abnormal effect either in increased mortality or decreased growth when compared with those unaffected.

PLATE 5.—Frost-damaged white spruce transplant. Pencil provides scale.

From the results obtained to date there is a strong suggestion that, under normal climatic conditions at least, white spruce transplants can be set out at any time during the frost-free season. Further data will be collected on height growth in order to ascertain the period it takes for transplants set out over a prolonged planting season to recover from the effects of movement. If the results agree with the hypothesis that movement effects only a temporary set-back, then many possibilities suggest themselves. For example, one of the drawbacks to the customary short spring or fall planting periods is the fact that capable and conscientious crews often cannot be obtained or trained over such a short period and the quality of the work suffers. Season-long planting could very well be considered as part of the work of a stand-by fire suppression crew. Such men take well to specialized training and during wet spells, when the fire-hazard is low, they could alternate on a planting programme. The transplants need only to be lifted from the nursery if and when they are required, and a highly trained crew could be kept busy all season.

SUMMARY

In 1952 a study was initiated on the Kananaskis Forest Experiment Station, which is situated in the subalpine forest region in Alberta, to investigate the possibility of continuous planting of white spruce throughout the frost-free period. Weekly plantings were undertaken and 2,016 transplants were set out in a statistically designed experiment in each of the 1952, 1953 and 1954 seasons, and data were collected on mortality, and on annual height growth of the survivors.

It was originally anticipated that success would be correlated with root growth, which was reputed to be active when aerial growth was inactive and relatively inactive when aerial growth was active. This periodicity of root growth was superficially investigated as part of the study, and appeared to be substantiated, but the survival results in the field plantations do not appear to be correlated.

The results obtained to date can be listed as follows:

1. Mortality has been acceptably low throughout the whole planting season, but has been highest whenever the soil at the time of planting was powder dry.
2. Height growth has been variously depressed depending on the period of planting. A hypothesis is offered to account for this behaviour and centres around the effect of the shock of transplanting on the organ primordia.
3. A concomitant effect of the depressed height growth is a chlorotic foliage and short needles.
4. The plants set out in the varying seasons appear to be recovering from the effects of transplanting.

The results obtained to date are encouraging and suggest the possibility of continued planting throughout the frost-free period, at least during seasons or periods of normal or above-normal precipitation. Unfortunately, no abnormally dry seasons were experienced during the course of the investigation.

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APPENDIX I

ANALYSIS OF VARIANCE, 1952 PLANTING, CUMULATIVE MORTALITY 1954

Source of var.	D. of F.	Ss	Mean sq.	F ratio	Significance
Totals	35	67	1·40	1·217	Not Sig.
Rows	5	7	2·40	2·087	Not Sig.
Columns	5	12	5·00	4·348	Highly Sig.
Treatments	5	25	1·15		
Error	20	23			

The effects of treatment were highly significant and t-tests were therefore carried out to determine the significance between planting months.

—	Difference of means	Significance
May vs June	+ 0·67	Not Sig.
May vs July	− 0·67	" "
May vs August	+ 1·17	" "
May vs September	0·00	" "
May vs October	+ 1·83	Highly Sig.
June vs July	− 1·34	Sig.
June vs August	+ 0·50	Not Sig.
June vs September	− 0·67	" "
June vs October	+ 1·16	" "
July vs August	+ 1·84	Highly Sig.
July vs September	+ 0·67	Not Sig.
July vs October	+ 2·50	Highly Sig.
August vs September	− 1·17	Not Sig.
August vs October	+ 0·66	" "
September vs October	+ 1·83	Highly Sig.

APPENDIX II

ANALYSIS OF VARIANCE, HEIGHT GROWTH 1953 OF 1952 PLANTING

Source of var.	D. of F.	Ss	Mean sq.	F ratio	Significance
Totals	35	15068·14			
Rows	5	560·86	112·172	< 1	Not Sig.
Columns	5	2472·04	494·401	3·103	Sig.
Treatments	5	8848·52	1769·704	11·107	Highly Sig.
Error	20	3186·72	159·336		

From the analysis of variance there are significant fertility trends across the planting site. In addition the effects of treatment were highly significant and t-tests were therefore carried out to determine the significance between months of planting.

—	Difference of means	Significance
May vs June	31·7″	Highly Sig.
May vs July	31·2	" "
May vs August	6·3	Not Sig.
May vs September	− 11·1	" "
May vs October	9·3	" "
June vs July	− 0·5	" "
June vs August	− 27·4	Highly Sig.
June vs September	− 42·8	" "
June vs October	− 22·4	" "
July vs August	− 24·9	" "
July vs September	− 42·3	" "
July vs October	− 21·9	" "
August vs September	− 17·4	Sig.
August vs October	3·0	Not Sig.
September vs October	20·4	Sig.

APPENDIX III

ANALYSIS OF VARIANCE, HEIGHT GROWTH 1954 OF 1952 PLANTING

Source of var.	D. of F.	Ss	Mean sq.	F ratio	Significance
Totals	35	57,951·28			
Columns	5	11,048·58	2,209·72	7·777	Highly Sig.
Rows	5	3,635·52	727·10	2·559	Not Sig.
Treatments	5	37,584·28	7,516·86	26·454	Highly Sig.
Error	20	5,682·90	284·14		

From the analysis of variance there are highly significant fertility trends over this planting block. The effects of treatment were highly significant and t-tests were therefore carried out to determine the significance between months of planting.

—	Difference of means	Significance
May vs June	4·6	Not Sig.
May vs July	49·6	Highly Sig.
May vs August	71·6	" "
May vs September	70·0	" "
May vs October	80·3	" "
June vs July	45·2	" "
June vs August	67·2	" "
June vs September	65·4	" "
June vs October	75·7	" "
July vs August	22·0	Sig.
July vs September	20·2	Not Sig.
July vs October	30·5	Highly Sig.
August vs September	− 1·8	Not Sig.
August vs October	8·5	" "
September vs October	10·3	" "

APPENDIX IV

ANALYSIS OF VARIANCE, MORTALITY 1954 OF 1953 PLANTING

Source of var.	D. of F.	Ss	Mean sq.	F ratio	Significance
Totals	35	951			
Rows	5	152	30·4	2·815	Sig.
Columns	5	75	15·0	1·389	Not Sig.
Treatments	5	507	101·4	9·389	Highly Sig.
Error	20	217	10·8		

From the analysis of variance there are significant fertility trends over this planting block. The effects of treatment were highly significant and t-tests were therefore carried out to determine the significance between months of planting.

—	Difference of means	Significance
May vs June	− 1·4	Not Sig.
May vs July	− 2·0	" "
May vs August	−10·0	Highly Sig.
May vs September	− 7·5	" "
May vs October	− 0·9	Not Sig.
June vs July	− 0·6	" "
June vs August	− 8·6	Highly Sig.
June vs September	− 6·1	" "
June vs October	+ 0·5	Not Sig.
July vs August	− 8·0	Highly Sig.
July vs September	− 5·5	" "
July vs October	+ 1·1	Not Sig.
August vs September	+ 2·5	" "
August vs October	+ 9·1	Highly Sig.
September vs October	+ 6·6	" "

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