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THE DURABILITY OF SCARIFIED SEEDBEDS FOR SPRUCE REGENERATION

By

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FOR

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Scarified seedbeds in O (Devil's Club) site type are rapidly invaded by thimbleberry (Rubus parvuflorus). Assistant is standing at centre of scarified seedbed that was bare mineral soil 4.9 feet wide three years before. Vegetation on areas not scarified was one to two feet high at that time.

SUMMARY

The effective life of machine-scarified seedbeds was investigated on 17 areas in the Prince George Forest District. All areas were on sites of average or better productivity for the region.

On each area from one up to a maximum of five sample plots were established, making a total of 33 plots distributed over a number of sites, years, and methods of scarification. In each plot, seedbeds were selected at random along scarified strips so that they represented a range in size from one foot square to 6.6 feet square.

Seedbeds were seeded in the year of scarification (SY0), and one (SY1), two (SY2), three (SY3), and four (SY4) years after being scarified. When all these seeding treatments had been concluded, 310 seedbeds were under observation on each plot.

Because nature could not be relied upon to provide a constant supply of seed, seedbeds were spot-sown artificially to simulate an annual natural seedfall. Thus the results of the study are also an indication of what to expect after artificially seeding strips which were scarified originally to induce natural regeneration.

The criterion of effectiveness was termed "success" and it was rated as the per cent of seeded seedbeds with one or more healthy spruce seedlings in relation to the age and size of the seedbed since the date of scarification. In addition to these main related factors, the influence of site-quality, size of tractor, and the interval of time between logging and scarifying also was examined.

Seeding year had a definite effect, and success decreased with the passage of time between scarifying and seeding. Mean success was 62.8 per cent for SY0, and 52.7, 38.7, 36.9, and 29.0 percent respectively for SY1, SY2, SY3, and SY4.

Success varied directly with seedbed size. On large seedbeds, survival was greater and the decrease due to seeding-year effect was much less than on small seedbeds. The overall success was 44.0 per cent at the end of the first growing season, and 45.7, 40.1, 33.9, and 26.9 per cent respectively at the end of the second, third, fourth, and fifth growing seasons (when seeding year was ignored and the per cent of all seedbeds with one or more spruce seedlings was averaged each season).

There were no such clear results for success in relation to the size of the bulldozer, site-type, and interval of time between logging and scarifying, because only a few confounded conditions were available for sampling. However, there are indications that:

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- success on plots scarified by large tractors is greater than on plots scarified by medium and small tractors,
- plots on the vegetation site-type classified as Aralia-Oakfern had slightly better success than plots on a Devil's Club site, and AD. O
- ? differences between pre-logging and post-logging scarification were not significant.

When the 'per cent success' of spruce is converted to a more familiar stocking per cent for the average scarified acre on a mil-acre basis, the principal results are:

- a stocking of 50.5 per cent in four years if the area was naturally or artificially seeded the same year it was scarified,
- a decrease to 32.8 per cent stocking if seeding occurs one year after site preparation, and
- unsatisfactory stocking if seeding occurs at intervals longer than one year after scarification. In this instance, it has been predicted that, to ensure success, the number of viable seeds required would range from as many as 11 for a 6.6-foot-square plot to 25 for a one-foot-square plot.

Other species were present on the seedbeds together with the spruce. They were balsam, Douglas-fir, lodgepole pine, hemlock, aspen, cottonwood, and birch, all from natural seedfall. Only balsam and birch were found on all plots.

The success of balsam and birch, rated in the same way as spruce, varied with seedbed size but not with seeding year.

Turning now to measures of growth, the average height of tallest seedlings at the end of four growing seasons was:

- spruce - 3.9 ins.,
- balsam - 1.9 ins., and
- birch 11.9 ins.

The average height of spruce seedlings did not vary with seedbed size but after the second growing season the seeding-year effect resulted in decreased average height of spruce and balsam seedlings, i.e. the average height of SY1 seedlings was less than SY0 seedlings of the same age, that of SY2 seedlings less than SY1 seedlings, and so on.

The vigorous growth and the abundance of birch seedlings are a potential threat to spruce seedling survival.

The very slow height growth of the spruce seedlings is a disturbing feature, especially when we recall that the sample areas have high site-values. If a generally poor seedling performance is confirmed by a survey of all scarified areas, then site preparation and planting, rather than scarifying and seeding, is recommended on Devil's Club and Aralia-Oakfern sites to ensure a more profitable realization of their potential productivity.

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INTRODUCTION

In the spruce-alpine fir forests of interior British Columbia scarification with a bulldozer blade is proving to be an expeditious means of site preparation, preceding natural or artificial regeneration.

The annual scarification program to promote natural seeding has increased from trials on 243 acres in 1956 to 15,530 acres during 1965, even though the treatment is generally restricted to about 30 per cent of the logged acreage.

In the Prince George Forest District, the results of a natural regeneration survey, based on 6,549 acres of scarification, have been promising and indicate that white spruce should be well-represented in the new stand. In fact, Gilmour and Konishi (1965) report that the average spruce stocking is 44 per cent by mil-acre quadrats, and that, if all species are counted, the stocking is 49 per cent with a range from 4 to 94 per cent.

This variation in natural stocking is not surprising. It stems from the fact that many events control the success or failure of this method of regeneration and seldom occur in an ideal sequence of desirable interactions. Although we need not list all the events, the primary factors dictating success or failure are abundance of seed supply, control of biotic enemies, exposure of mineral soil in adequate numbers of well-distributed seedbeds, absence of brush and weeds, favourable weather, and (when 10 or more dollars are invested per acre in scarification) the durability of the prepared seedbed.

It is of value to know the effective life of a seedbed because, if it spans several years, it provides a welcome leeway in the vital matter of timing operational scarification programs. First, the timing of scarification to coincide with very good seed crops is less critical. Secondly, it becomes more practical to cope with administrative difficulties (p. 15 Gilmour and Konishi 1965). Thirdly, it affords an opportunity to seed artificially in a year subsequent to the year of scarification providing the prospect of successful natural seeding dims in the face of lost seed sources or poor seed-crops.

Obviously, several questions arise. Is the life-span one, two, or five years after the year of scarification? How important is size of the seedbed, with particular reference to its re-occupation by weeds (Stettler 1958)?

Some of the answers have resulted from the present study.* Its main purpose is to advise on the length of time scarified seedbeds remain effective media for establishment of spruce regeneration. It reports also on behaviour of the associated species of balsam and birch, and comments briefly on the influence of vegetation site-type, tractor size, and interrelation of times of logging and scarifying with the speed of vegetative invasion of prepared seedbeds.

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*Based upon results from Experimental Project 528 - The Influence of Time on the Effectiveness of Scarified Seedbeds.

OBJECTIVE

The objective was to determine how long scarified seedbeds remain effective as media for the germination, survival, and growth of spruce.

METHODS AND PROCEDURES

This study was carried out in the Prince George region on a number of timber sales scarified by normal operational procedures. Scarifying equipment included a variety of crawler tractors equipped with bulldozer blades.

Within selected timber sales, plots were established after examination showed they were large enough, sufficiently uniform with regard to site, and had the required range in size of seedbeds. Figure 1 and Table 1 show the number and distribution of the plots finally selected.

Each plot consists of 310 mineral soil seedbeds produced by scarification. The individual seedbeds were selected and staked on irregular transects traversing the plot area. The minimum dimension of margin-to-margin width of mineral soil was measured on each seedbed. The margin of a seedbed was either forest floor or slash accumulations. The minimum width recorded was one foot, and the largest 6.6 feet. Large scarified areas frequently had several maximum-sized seedbeds on them with their centres seven or more feet apart.

Within each plot, 50 seedbeds, selected at random, were seeded the same year they were scarified (seeded year zero or SY0). Each succeeding year 50 seedbeds were seeded (SY1, SY2, SY3, SY4), and an additional 15 seedbeds were hand-scarified and seeded each year to approximate the original conditions of scarification.

Seeding was done each fall starting late in September and was completed by October 15. Before seeding, all natural coniferous seedlings were removed from the seedbed. Renewed seedbeds were checked for width, cleared of vegetation with a sharpened dutch hoe, and then seeded. Seed was sown near the stake, at the centre of the seedbed. The seeder was held about 10 inches above the ground and the seed fell within a circular area averaging 10 inches in diameter. A swedish hand seeder (page 42, Research Review, 1958), set to deliver approximately 12 viable seeds, was used the first two years (1958 and 1959). For the remaining years (1960, 1961 and 1962), the "M and B" seeder was used (page 34, Research Review, 1960). It delivered approximately 15 viable seeds.

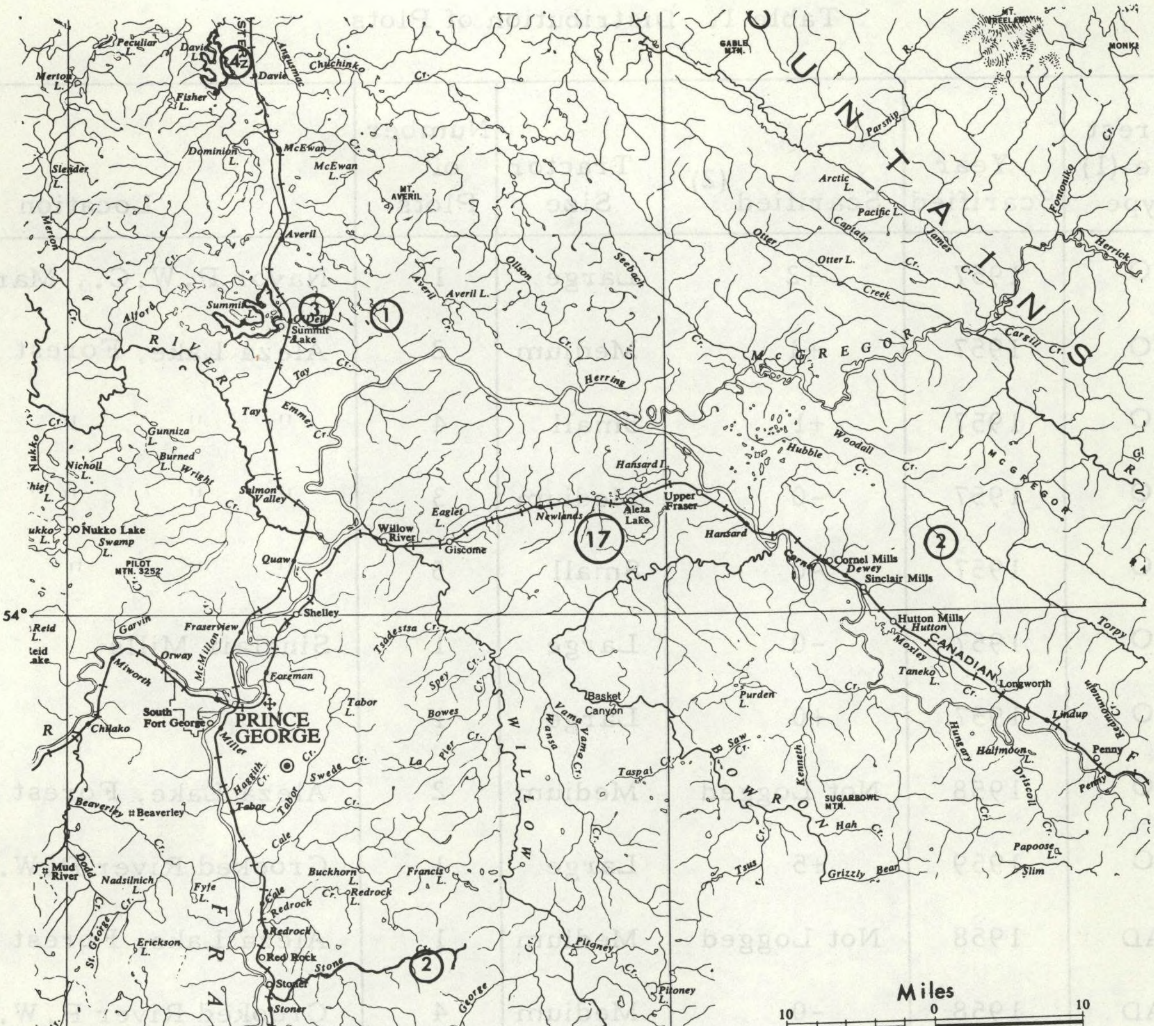

Figure 1

Number and approximate location of sample plots. Inset outline of British Columbia shows general location of study area.

Table 1. Distribution of Plots

Forest Site (1) Type	Year Scarified	Scarified (2)	Tractor Size	Number of Plots	Location
O	1957	+2	Large	1	Navor P.W.C., Mary Lake
O	1957	+1	Medium	2	Aleza Lake, Forest Res.
O	1957	+1	Small	4	" " "
O	1957	-0	Medium	3	" " "
O	1957	-0	Small	5	" " "
O	1957	-0	Large	1	Sinclair Mills
O	1957	+0	Large	1	" "
O	1958	Not Logged	Medium	2	Aleza Lake, Forest Res.
O	1959	+5	Large	1	Crooked River P.W.C.
AD	1958	Not Logged	Medium	1	Aleza Lake, Forest Res.
AD	1958	-0	Medium	4	Crooked River P.W.C.
AD	1959	+5	Large	2	" " "
AD	1959	+1	Large	2	Navor P.W.C., Mary Lake
AD	1959	+1	Medium	1	" " Stone Creek
AD	1959	Not Logged	Medium	1	" " " "
AD	1960	+0	Large	1	15 Mile Rd., Wells Rd.
AD	1961	+1	Large	1	Crooked River P.W.C.

(1) O = Oplopanax Site Type. AD = Aralia-Dryopteris Site Type.

(2) Years scarified before (-) logging or after (+) logging.

The seeded seedbeds were examined in early summer (June to mid-July) and the fall (September) of 1959 and 1960. In 1961, 1962, and 1963 they were examined only in the fall. Spruce and other tree seedlings were counted and recorded. On the second fall examination and on each succeeding examination, the height of the tallest seedling of each tree species present was recorded.

Seedbed examinations made during the five years of the study totalled 17,980.

Control data allowed adjustment for variations in weather conditions, natural seedfall, rodent depredations, and other uncontrolled variables. It was assumed that the results from SY0 seedbeds and the series of renewed seedbeds, seeded in each of the succeeding four years, varied in response to the uncontrolled variables only, whereas all the other seeded seedbeds had the added effects of passage of time. Complete control was not attained because renewing seedbeds by hand methods did not make them identical to the newly scarified condition. The control data from the SY0 and the renewed seedbeds permitted the adjustment of all data to a base year, thus reducing the effects of uncontrolled variables.

The year 1959 was selected as base year because monthly precipitation and mean monthly temperatures during the growing season were close to the long-term averages as measured by weather data from the Prince George Airport weather station.

ANALYSES OF DATA

Regression analyses of the number of seedlings on size of seedbed were made and the effects of time of seeding and seedbed size were clearly indicated. Analyses were then made on the basis of number of seeded seedbeds with one or more seedlings at the end of each of five growing seasons. Comparisons between tractor-sizes, site-types, and time-of-scarification to time-of-logging were difficult because sampling was not orthogonal.

RESULTS AND DISCUSSION

Results are reported in terms of per cent of seeded seedbeds with one or more seedlings and this is termed 'success'. Tabulated summaries of the data are presented in the appendix.

Effects of Time and Seedbed Size

The decreasing effectiveness of the seedbeds with passage of time after scarification, due mainly to regrowth of vegetation, is apparent in the success by seeding years. Mean success of the seedbeds seeded the same year as scarified (SY0) is 62.8 per cent; and 52.7, 38.7, 36.9, and 29.0 per cent respectively for SY1, SY2, SY3, and SY4.

Size of seedbed had an important effect on success. Success was lower on small seedbeds than on larger ones, and the decrease with successive years and with time of seeding was also greater on small seedbeds than on large ones. Figure 2 shows the effects of seedbed size and the adverse effects on the establishment of seedlings with the passage of time between scarification and seeding.

Overall success in terms of per cent of seeded seedbeds with one or more seedlings was 44.0 per cent at the end of the first growing season, and 45.7, 40.1, 33.9 and 26.9 per cent respectively at the end of the second, third, fourth, and fifth growing season.

The seeding year with the best results is SY0. The yearly decline in success of these seedbeds seeded during the scarification year is clearly shown for a period of four years. At the end of four growing seasons, 23.3 per cent of the smallest size-class seedbeds have one or more seedlings, while 51.7 per cent of the largest size-class have one or more seedlings. There is no sign of a levelling off of the annual decrease in number of seedbeds with seedlings.

The steady decrease in success from year to year with no sign of levelling off may be cause for concern. However, the above results are derived from data adjusted to minimize the effects of the uncontrolled variables (weather, natural seedfall, rodent depredations) and it is assumed that these results depict the situation that would prevail under a continuous regime of the base year, 1959. But weather, natural seedfall, and other conditions varied from year to year. The data without adjustment, presented in Figure 3, shows an increase in average success with the passage of time, due to the seeding in of natural seedlings, 46.0 per cent at the end of the first growing season, and 54.5, 55.1, 57.4 and 62.0 per cent respectively at the end of the second, third, fourth, and fifth growing season. However, the decrease in germination and survival with the passage of time between scarification and seeding (seeding year effect) and the effect of seedbed size are as prominent as in the adjusted data, a further indication of the lasting effectiveness of the larger seedbeds.

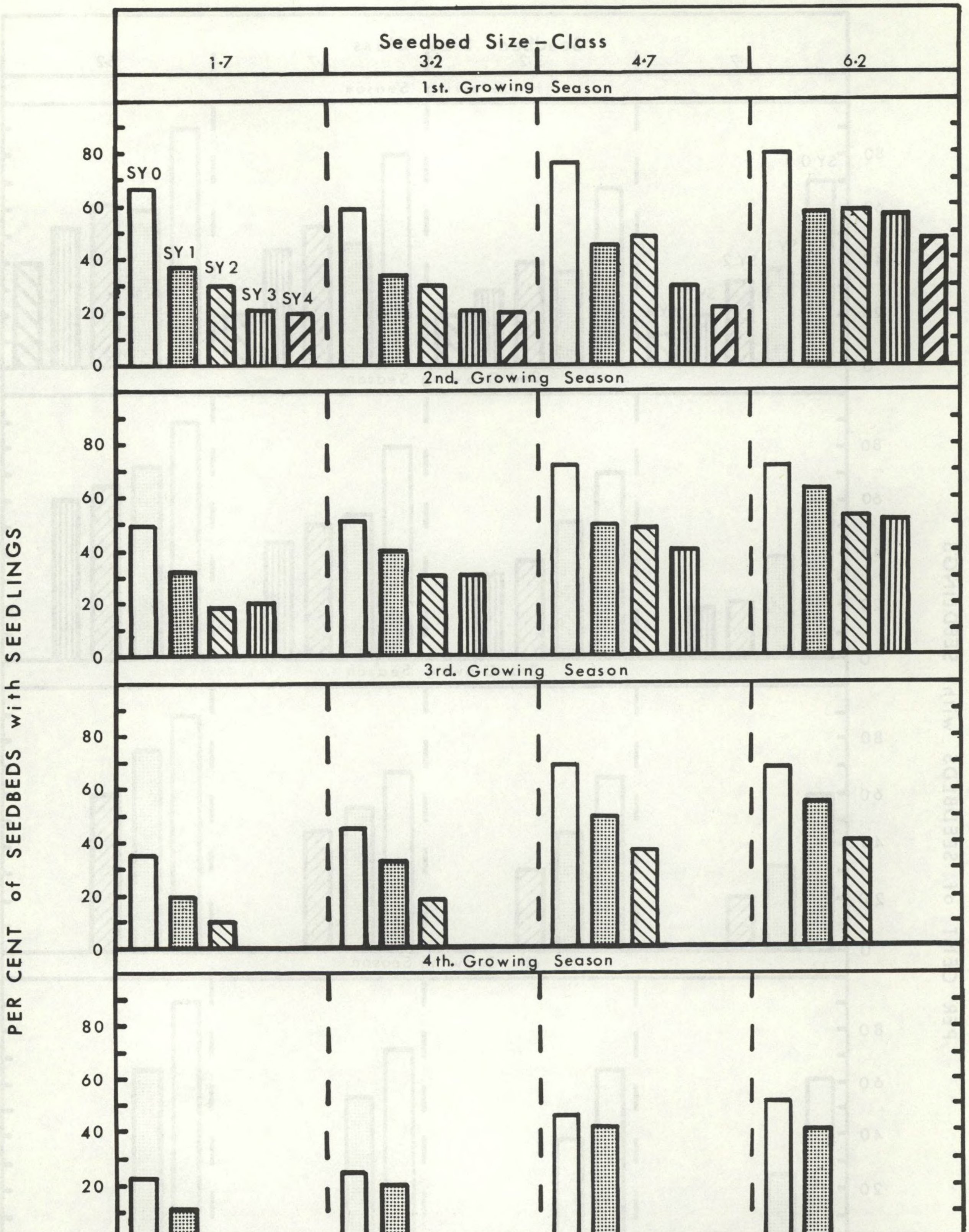

Figure 2

Per cent of seeded seedbeds with spruce seedlings (adjusted to base year 1959) at the end of the first, second, third and fourth growing seasons, by seedbed size-classes and seeding years. SY0 - seeded same year as scarified; SY1 - seeded one year after scarification, and so on.

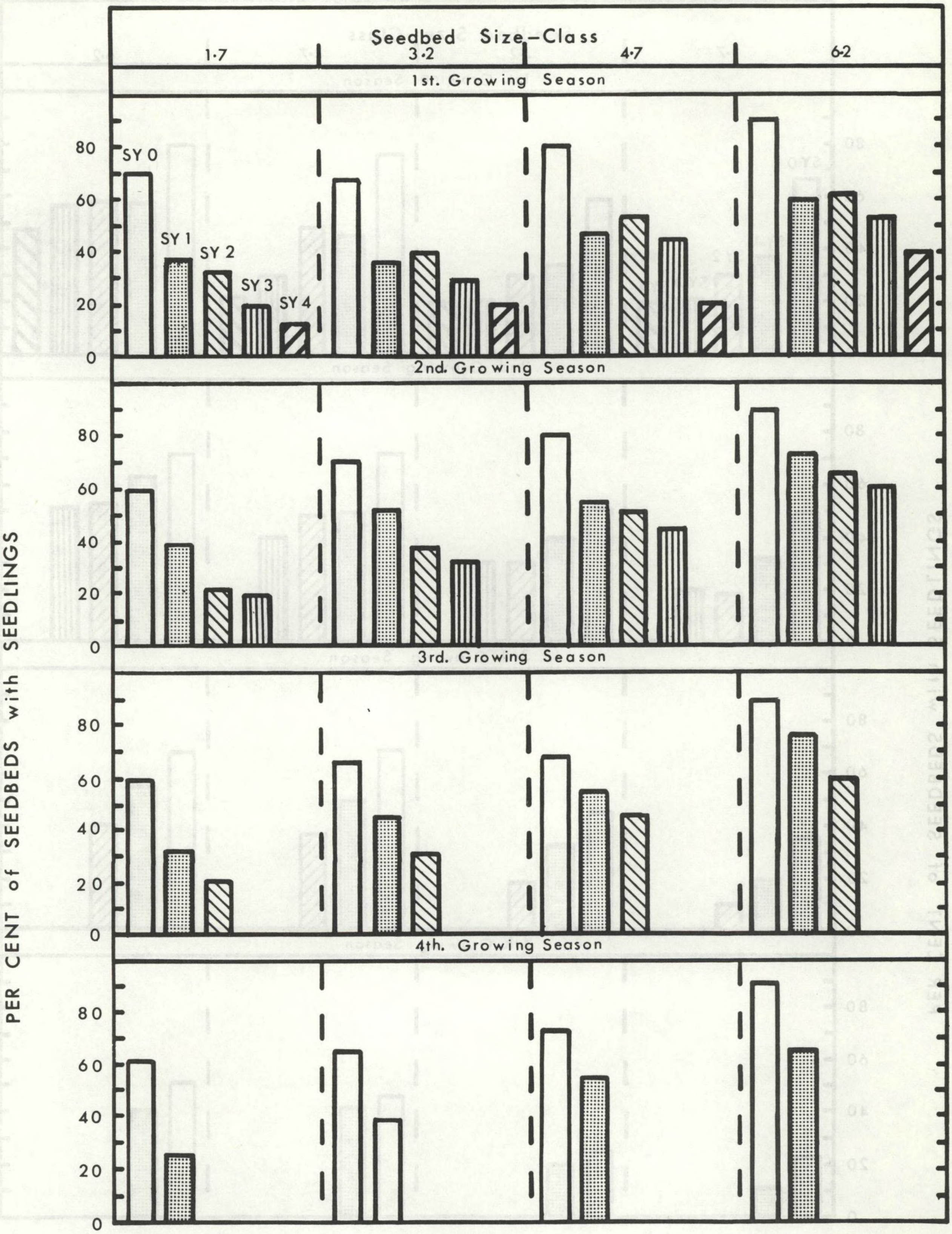

Figure 3

Per cent of seeded seedbeds with spruce, seedlings (not adjusted to base year) at the end of the first, second, third, and fourth growing seasons, by seedbed size-classes and seeding years.

Other Effects

Analyses of the data for the effects of tractor size, vegetation site types, and interrelation of times of logging and scarification were limited. Comparisons were made between sets of plots that were treated alike in all respects except for the factor examined. These comparisons are not entirely satisfactory because of small and varying numbers of samples in the sets. In addition there exists a locality bias. For instance, only at Aleza Lake Forest reserve was the smallest tractor (TD6) used; also site types tended to be concentrated by locality. Hence the following results, adjusted to base year, are presented with the reservation that they indicated trends rather than demonstrate differences.

Mean success for large tractors (D9, D8, TD14) was 44.0 per cent, for medium tractors (D6, TD9) was 27.0 per cent, and for small tractors (TD6) 21.9 per cent. The large tractor mean differs significantly ($P = .01$) from medium and small tractor means. The difference between medium and small tractor means is not significant ($P = .05$). This result is attributed to the higher proportion of large-sized seedbeds on plots scarified by the large tractors. The average percentage of large-sized seedbeds (width over 5 feet) on plots scarified by large tractors was 71 per cent, and for plots scarified by medium and small tractors was 38 and 27 per cent, respectively.

During the study the author had a distinct impression that the results were better on plots in the AD (Aralia-Oakfern) site type than on plots in the O (Devil's Club) site type. Analysis of the data, however, support this impression only partially. Mean success for plots scarified by medium tractors in unlogged stands was 61.6 per cent in AD site type, and 41.1 per cent in O site type. Mean success for plots scarified immediately before scarifying was 34.7 per cent in AD site type, and 26.3 per cent in O site type. These differences are significant ($P = .05$). Other combinations of tractor size and time-of-scarification to time-of-logging showed no significant differences.

No indication of an interrelationship between times of scarification and logging arose from the few comparisons that could be made. In other words, these limited tests detected no difference in results between pre-logging and post-logging scarification.

Other Species

Seedlings of other tree species found on seedbeds seeded to spruce were tallied. Balsam, Douglas-fir, lodgepole pine, hemlock, aspen, cottonwood, and birch, all from natural seedfall, were found; but only balsam and birch seedlings were found on all plots and the results reported. The percent of seedbeds with one or more seedlings arranged by seeding years is shown in Figure 4. Spruce is included for comparison.

Note that, unlike spruce, there does not appear to be a seeding year effect upon balsam and birch. The age of the birch seedlings cannot be related to seeding year because birch seedlings were not removed before the seeding. Perhaps the passage of time does not decrease the "receptiveness" of the scarified seedbeds for balsam to the same extent it does for spruce.

Balsam seedlings were few in number in 1960 and 1961 (15.7 per cent and 7.5 per cent success respectively) and confined to plots adjacent to or in unlogged stands. In 1961 there was a good seed crop for balsam and seedlings were numerous in 1962 and 1963 (37.4 per cent and 43.4 per cent success, respectively).

The species other than spruce occurred with high frequency on seedbeds that had spruce seedlings - only 16 per cent of the balsam seedlings were on seedbeds without spruce seedlings, and 24 per cent of the birch occurrences were on seedbeds without spruce and/or balsam seedlings.

An analysis of the effect of seedbed size was not made for balsam and birch, but a relationship is indicated from a sample of 1,000 seedbeds drawn at random from the data. Balsam successes (i.e., seedbeds with one or more seedlings) occurred in a ratio of about 3:4:6 for small, medium, and large seedbeds; birch in a ratio of about 2:3:4, and spruce about 4:5:9. It is assumed from these results that successes vary with seedbed size.

No relationships of tractor size, site type, or time-of-scarifying to time-of-logging, to the occurrence of balsam or birch seedlings were found.

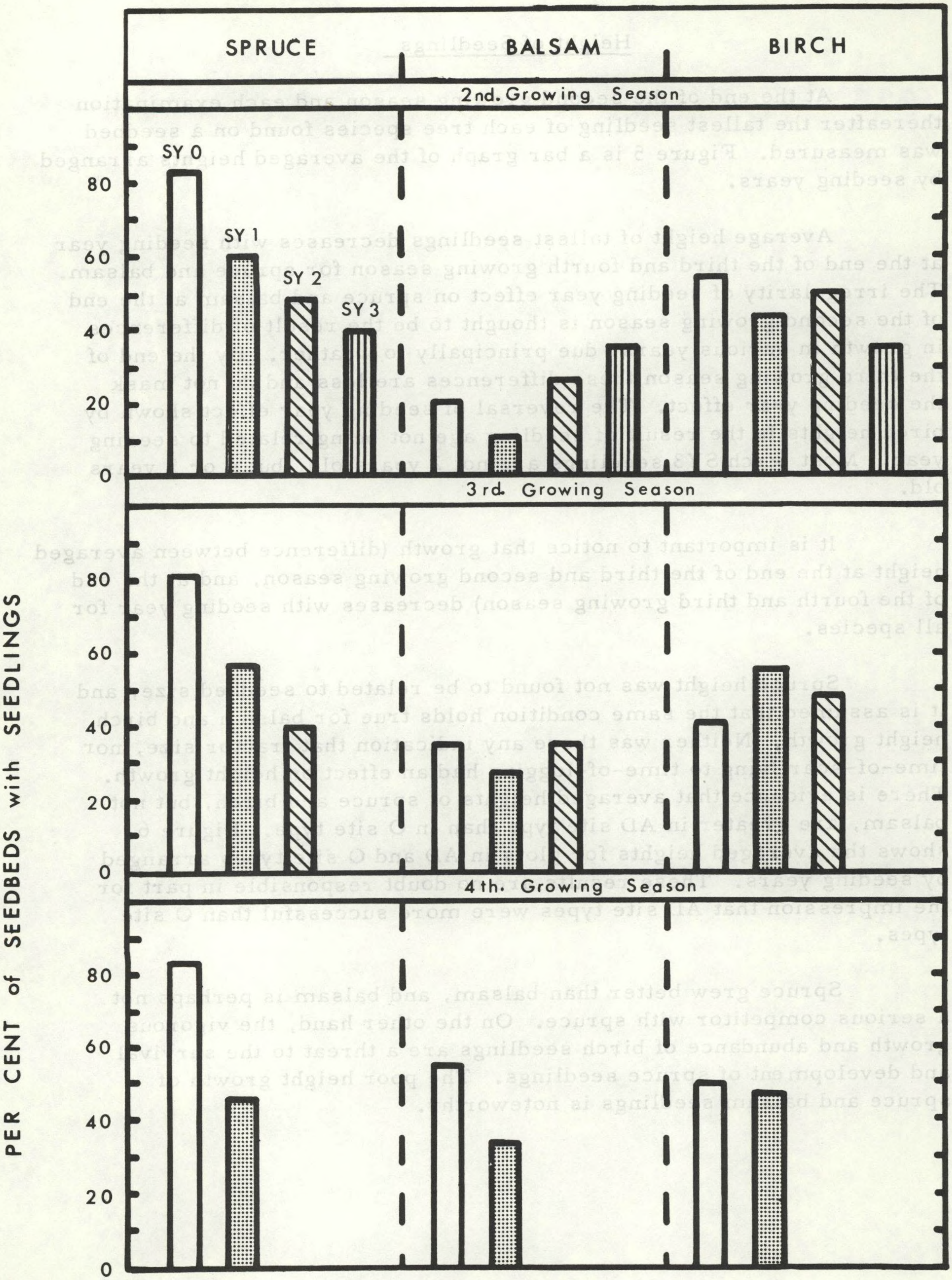

Figure 4

Per cent of seedbeds seeded with spruce, balsam, and birch seedlings at the end of the second, third, and fourth growing seasons, by seeding years.

Height of Seedlings

At the end of the second growing season and each examination thereafter the tallest seedling of each tree species found on a seedbed was measured. Figure 5 is a bar graph of the averaged heights arranged by seeding years.

Average height of tallest seedlings decreases with seeding year at the end of the third and fourth growing season for spruce and balsam. The irregularity of seeding year effect on spruce and balsam at the end of the second growing season is thought to be the result of differences in growth in various years, due principally to weather. By the end of the third growing season these differences are less and do not mask the seeding year effect. The reversal of seeding year effect shown by birch heights is the result of seedling age not being related to seeding year. Most birch SY3 seedlings are not 2 years old, but 4 or 5 years old.

It is important to notice that growth (difference between averaged height at the end of the third and second growing season, and at the end of the fourth and third growing season) decreases with seeding year for all species.

Spruce height was not found to be related to seedbed size, and it is assumed that the same condition holds true for balsam and birch height growth. Neither was there any indication that tractor size, nor time-of-scarifying to time-of-logging had an effect on height growth. There is evidence that averaged heights of spruce and birch, but not balsam, are greater in AD site type than in O site type. Figure 6 shows the averaged heights for plots in AD and O site types arranged by seeding years. These results are no doubt responsible in part for the impression that AD site types were more successful than O site types.

Spruce grew better than balsam, and balsam is perhaps not a serious competitor with spruce. On the other hand, the vigorous growth and abundance of birch seedlings are a threat to the survival and development of spruce seedlings. The poor height growth of spruce and balsam seedlings is noteworthy.

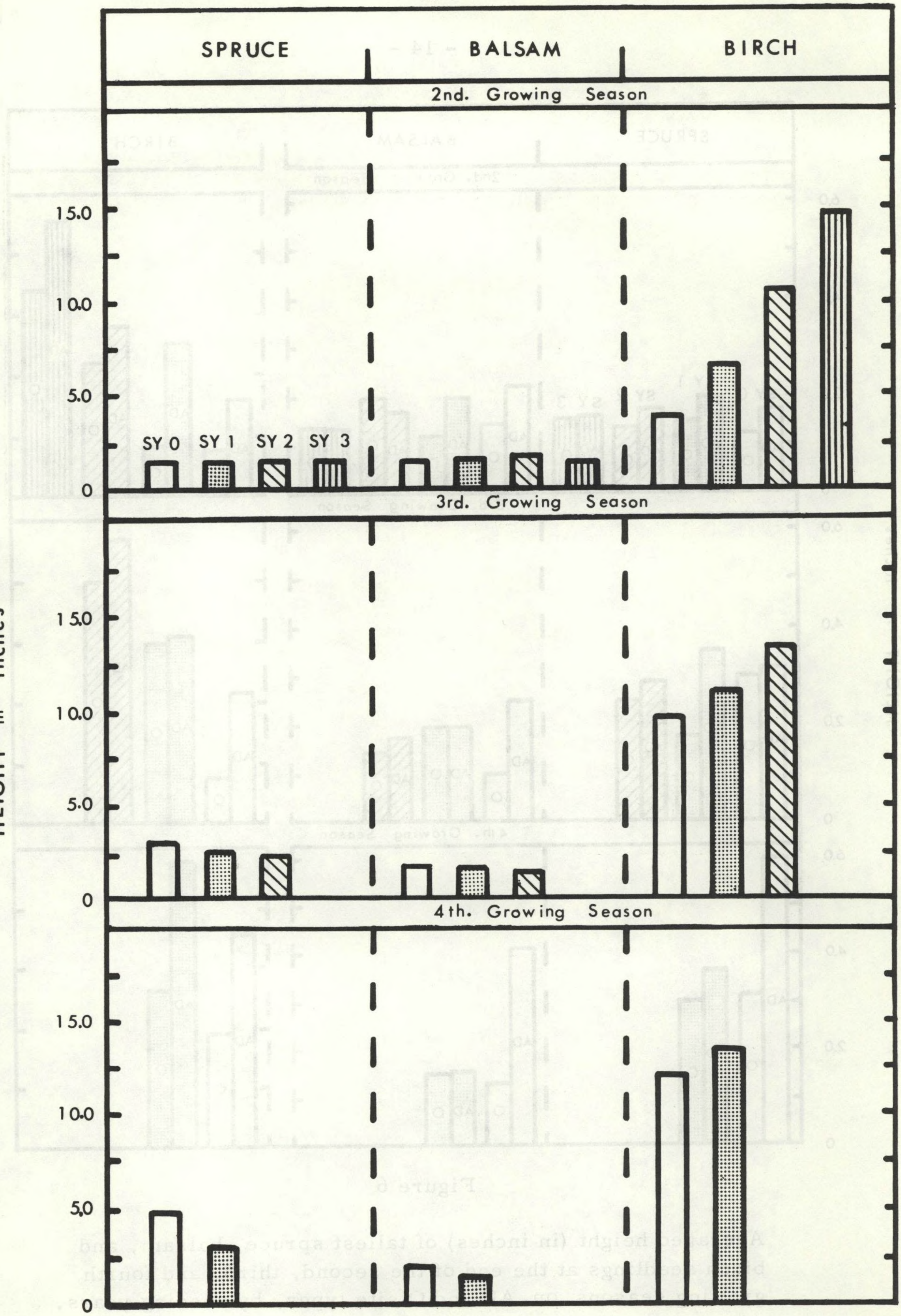

Figure 5

Averaged height (in inches) of tallest spruce, balsam, and birch seedlings at the end of the second, third, and fourth growing seasons, by seeding years.

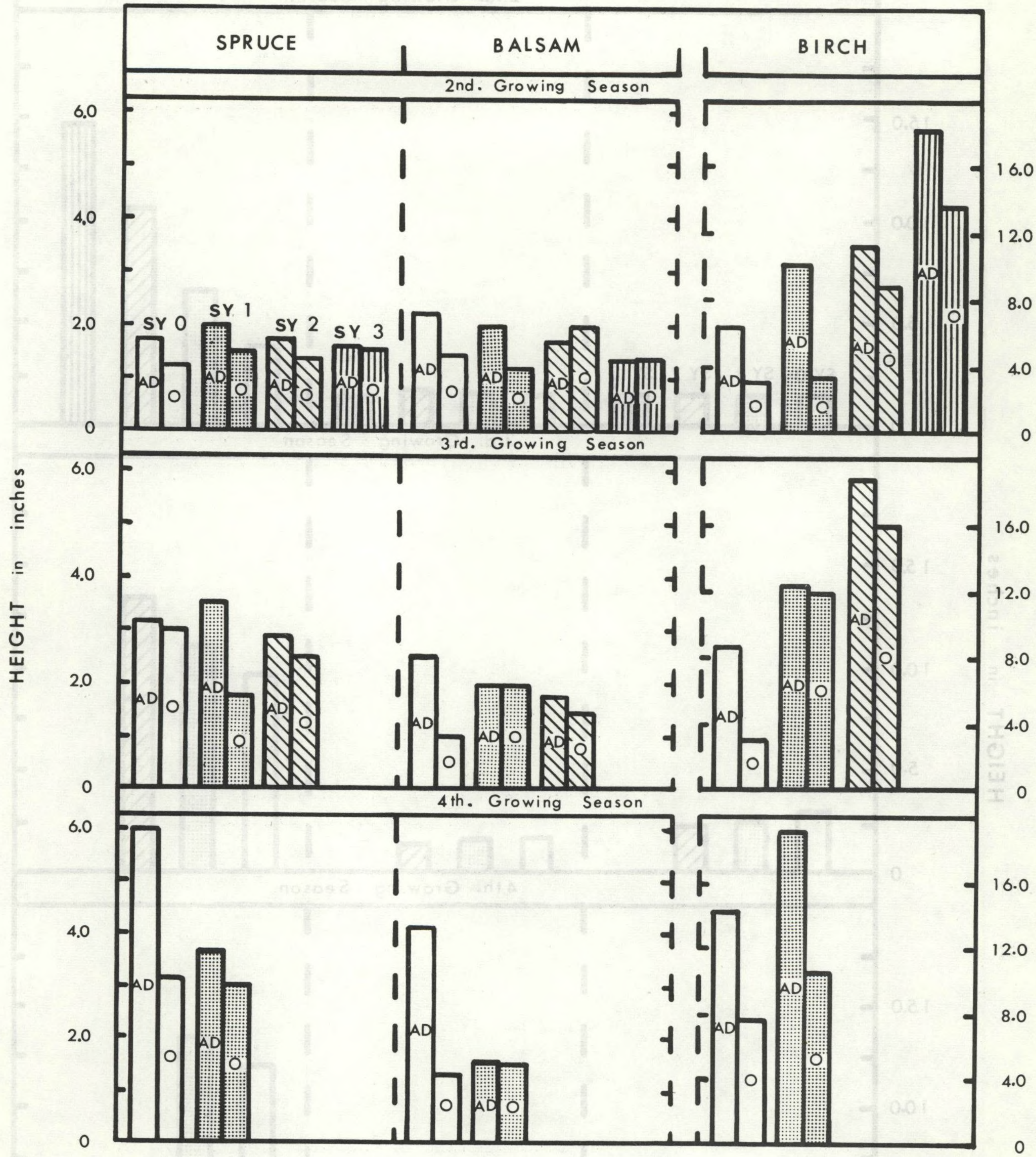

Figure 6

Averaged height (in inches) of tallest spruce, balsam, and birch seedlings at the end of the second, third, and fourth growing seasons on AD and O site types, by seeding years.

INTERPRETATION OF RESULTS IN TERMS OF SPOT SEEDING

On the basis of this study and several assumptions, the results from spot seeding scarified areas when natural seed is unavailable or inadequate can be predicted. Scarification as practiced in the Prince George region results in mineral soil exposure that averages 34 per cent of the area, or 15,000 sq. ft. per acre (Gilmour and Konishi, 1965, page 7). Assuming that seedbed sizes occur in the same ratio as found for the plots of this study there is room for 660 seedbeds per acre distributed as follows:

	Seedbed Size-Class -(feet)			
	1.0-2.4	2.5-3.9	4.0-5.4	5.5-6.6
Number of seedbeds	145	136	97	282

This corresponds to the average distribution of seedbeds found by Gilmour and Konishi - that is, 65 per cent (= 650) of the mil-acres on an acre have one square foot or more of seedbed.

Assuming that the 660 available seedbeds are spot-seeded and applying the results from summary 2 in the appendix, the number of stocked seedbeds was calculated and converted to a stocking figure for SY0 and SY1 seedbeds at the end of the fourth growing season and for SY2 seedbeds at the end of the third growing season. These results are presented in Table 2 on page 16. Included is the number of viable seeds required to produce two surviving seedlings at the end of the fourth growing season, estimated from data not used in this report.

It is evident from these results that seeding the same year as scarification is essential to obtain the best results. The predicted number of stocked seedbeds at the end of the fourth growing season following seeding produces adequate stocking of 50.5 per cent on a mil-acre basis and the quantity of seed required is small. Seeding one growing season after scarification reduces stocking to 32.8 per cent, and doubles the amount of viable seed required. When seeding is delayed until two growing seasons have passed after scarification, stocking is unsatisfactory and the quantity of viable seed required is large. It should be noticed that the SY2 stocking of 28.7 per cent is at the end of the third growing season after seeding. Advance regeneration, regeneration of other coniferous species, and regeneration occurring on seedbeds other than mineral soil would improve stocking slightly.

Table 2. Per cent Stocking on Average Scarified Acre

Seedbed Size-Class feet	Seedbeds Available	Success[1.] SY0	SY1	SY2	No. of Stocked Seedbeds SY0	SY1	SY2	No. of Viable Seeds per Seedbed SY0	SY1	SY2
1.0-2.4	145	61.8	25.9	21.6	89	38	31	8	16	25
2.5-3.9	136	64.3	37.9	31.0	87	52	42	5	13	13
4.0-5.4	97	72.7	55.1	46.0	71	53	45	3	11	13
5.5-6.6	282	91.6	65.6	59.8	258	185	169	2	9	11
Total	660				505	328	287			
Milacre Per Cent Stocking					50.5	32.8	28.7			

1. Success - per cent of seeded seedbeds with one or more seedlings and is rated at the end of the fourth growing season for SY0 and SY1 and the end of the third growing season for SY2.

Scarification can be made more effective by increasing the area of exposed mineral soil. This would not only provide more seedbeds, but would also increase the proportion of the large seedbeds that are more effective. Cost of scarifying could be expected to increase by this practice.

OBSERVATIONS

A study such as this with repeated examinations of the same areas engenders in the examiner a familiarity with the plots and their responses. The following observations are based on familiarity and not experimental evidence but I hope they add to this study.

Plots on sandy loam soils had more seedlings in SY0 and SY1 years than plots on silty and clay soils. However, sandy loam plots were quickly overgrown with vegetation. Especially is this the case in Oplopanax (Devil's Club) site type where sandy loam plots were obliterated in three years with a rank growth of thimbleberry (*Rubus parviflorus*) three feet tall. (See photograph page ii)

Seedbeds with a rough surface had more seedlings than smooth seedbeds. Even the slight roughening made by tractor tracks improved the seedling catch. On the other hand, so-called mixed seedbeds, that is, a mixture of duff and mineral soil rolled up by the bulldozer blade and then spread out, were poor seedbeds in terms of establishment of seedlings; but height growth of the few seedlings established on mixed seedbeds appeared better than average. To produce the ideal seedbed requires an implement that screefs, that is, scrapes off the vegetation and most of its roots, and that cultivates or harrows the bare mineral soil to produce a rough seedbed.

Frost heaving occurred on seedbeds on heavy-textured soils, but is not considered a serious factor in spruce establishment. A record of frost heaving was kept for several plots early in the study. Frost heaving of spruce seedlings was recorded on 267 seedbeds. Two growing seasons later 243 of these seedbeds still had spruce seedlings on them. Many of the seedlings had exposed "hockey stick" roots, but otherwise did not appear to differ in vigor or average height from normal seedlings.

Thimbleberry is the most vigorous plant invader of scarified seedbeds in the study area. It grows from root sprouts, proliferates rapidly from its rhizomes and can obliterate a large seedbed in three years. It competes with spruce seedlings for moisture and nutrients and produces a dense shade. Most spruce seedlings that survive its competition are smothered by its heavy leaf fall. Thimbleberry is most plentiful in the O site type, especially after logging. Birch seedlings are vigorous competitors, too. The abundance of birch seedlings varies with number of seed trees, and one birch seed tree per acre can establish seedlings on a large number of scarified seedbeds. The felling of birch residuals would greatly reduce the number of birch seedlings, although there would still be a seed source in the unlogged margins. After the third year many birch seedlings are browsed sufficiently to check their growth, but not, unfortunately, to reduce the threat to survival of spruce seedlings. Western coolwort (Tiarella unifoliata) is the herbaceous plant most frequently found on scarified seedbeds in O and AD site types. It begins to occupy seedbeds after two or three years. It is, of course, a competitor, but more in the sense that it occupies space and is thus more serious on small seedbeds than large ones. Oak fern (Gymnocarpium dryopteris), sarsaparilla (Aralia nudicaulis), woods' horsetail (Equisetum sylvaticum) and bunchberry (Cornus canadensis) are also, more or less, the same kind of competitors, become established on seedbeds after two or three years, but occur less frequently than Tiarella.

Occasionally small areas occurred in slightly concave positions that received surface drainage from the surrounding terrain. These places usually had low success. The seedbeds tended to be definite depressions that flooded from spring snow melt, and in the fall in years when there were heavy rains. The few successful seedbeds in these places were mounds or hummocks. Vegetation offered serious competition on the mounds. Sedges (*Carex* spp.), Indian reed grass (*Cinna latifolia*), bluejoint grass (*Calamagrostis canadensis*) and horsetails (*Equisetum* spp.) not only became active competitors within two or three growing seasons, but their litter smothered seedlings.

Unfortunately no plots in Cornus-Moss site type were found for this study. The Cornus-Moss site type is well-suited for scarification. It has a living-moss and raw-humus layer several inches thick, lesser vegetation is relatively poor in species and abundance, approximately 70 per cent of the plant roots are in the humus and top inch or two of the soil. Furthermore, observations show that in the C-M site type scarified (screefed) seedbeds remain free from vegetation for four to five years. Glew (1963) found scarification costs to be low on C-M site types.

CONCLUSIONS AND RECOMMENDATIONS

For best results scarified areas should be seeded naturally or artificially the same year, and not later than one growing season after scarification. At present, prediction of good seed crops is uncertain, and it is impractical to schedule scarification to years of good seed crops for it means a crash program to scarify the backlog of unregenerated areas built up between good seed years. Artificial seeding is an alternative when seed crops fail, but this also presents difficulties. Broadcast seeding requires large quantities of seed which is expensive and often is not available at any price. Spot-seeding greatly reduces the quantity of seed required, although labour costs are increased.

Improved scarification to increase exposure of mineral soil is recommended. The maximum area possible is limited to 60 to 70 per cent of the total area because of the space occupied by stumps and slash accumulations, and an irregular distribution of regeneration is unavoidable.

The lack of a difference in results from pre-logging and post-logging scarification suggests that both leave and cut strips on alternate clear-cut strip timber sales be scarified. The leave strips should be winter-logged as soon as regeneration is established.

The height of spruce seedlings in this investigation averaged only 3.9 inches at the end of four growing seasons. This height growth (the average of the tallest seedlings on each seedbed) seems poor for sites of as high potential growth as the AD and O site types. Re-surveying is recommended for some of the scarified areas on which regeneration surveys have been made. The main purpose would be to assess the growth of the regeneration and incidentally any change in stocking. If the resurvey confirms the poor growth shown in this investigation, then a strong case has been made for planting these sites rather than scarifying them. To realize the high potential productivity inherent in O and AD site types, quick and adequate restocking with welldistributed thrifty spruce seedlings is essential.

Investigation of mechanical methods of site preparation for planting is warranted. Site preparation for planting can increase survival and growth of planted stock by reducing competition from vegetation, reduce planting costs, and improve spacing and stocking. With adequate site preparation the possibility of bullet or tube planting should not be overlooked.

On the basis of the results of this study and experience, I suggest that cut-over areas in O site type be regenerated by planting, accompanied by site preparation, in order to realize the high growth potential of these sites. Scarification is suggested for AD site types provided further study shows growth of regeneration to be satisfactory. Although there were no plots in CM site types in this study, I believe that regeneration can be satisfactorily established on this site type by scarification.

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APPENDIX

Tabulated Summaries of Data

Summary No. 1. Per cent of seeded seedbeds with spruce seedlings (adjusted to base year, 1959)

At the end of	Seeded Year	Seedbed Size-class (feet) 1.0-2.4	2.5-3.4	4.0-5.4	5.5-6.6	Mean
First growing season	SY0	67.4	58.7	75.9	79.1	75.3
	SY1	37.0	33.7	45.2	57.4	46.1
	SY2	31.4	30.4	48.5	58.7	45.2
	SY3	21.2	20.7	29.2	58.0	37.5
	SY4	20.1	19.6	21.8	47.8	29.0
Mean						44.0
Second growing season	SY0	49.5	51.3	72.2	72.2	67.5
	SY1	32.3	39.8	49.2	63.6	49.6
	SY2	18.5	31.6	48.2	53.0	40.0
	SY3	20.3	31.8	40.2	51.6	36.1
Mean						45.7
Third Growing season	SY0	34.9	46.6	69.2	68.0	62.1
	SY1	20.1	32.8	50.5	55.6	42.0
	SY2	10.5	18.5	37.7	41.3	26.4
Mean						40.1
Fourth growing season	SY0	23.3	24.6	46.5	51.7	45.1
	SY1	11.2	20.8	42.5	41.7	27.9
Mean						33.9
Fifth growing season	SY0	11.7	18.8	26.0	39.8	26.9

Summary No. 2. Per cent of seeded seedbeds with spruce seedlings (not adjusted to base year)

At the end of	Seeded Year	Seedbed Size-Class (feet) 1.0-2.4	2.5-3.9	4.0-5.4	5.5-6.6	Mean
First growing season	SY0	70.4	67.2	79.7	90.4	84.3
	SY1	37.9	36.7	46.4	59.7	48.1
	SY2	33.0	38.9	53.0	61.4	49.1
	SY3	19.8	28.9	44.3	53.5	39.4
	SY4	12.5	20.5	20.3	39.6	24.3
Mean						46.0
Second growing season	SY0	59.4	70.9	80.3	90.1	83.5
	SY1	38.6	52.3	54.4	73.1	59.8
	SY2	22.4	38.0	50.7	66.7	48.2
	SY3	19.3	32.4	44.4	60.7	39.4
Mean						54.5
Third growing season	SY0	59.0	66.0	68.4	89.0	80.8
	SY1	32.3	45.1	54.7	77.0	57.1
	SY2	21.6	31.0	46.0	59.8	39.6
Mean						55.1
Fourth growing season	SY0	61.8	64.3	72.7	91.6	83.1
	SY1	25.9	37.9	55.1	65.6	45.8
Mean						57.4
Fifth growing season	SY0	41.7	75.0	50.0	75.0	62.0

Summary No. 3. Per Cent of seedbeds with spruce, balsam and birch seedlings.

At the end of	Seeded Year	Spruce	Balsam	Birch
Second growing season	SY0	83.5	20.4	54.7
	SY1	59.8	11.4	43.2
	SY2	48.2	26.7	50.1
	SY3	39.4	35.2	35.2
Mean		54.5	22.6	44.9
Third growing season	SY0	80.8	35.2	41.4
	SY1	57.1	26.9	55.2
	SY2	39.6	35.1	48.3
Mean		55.1	31.3	50.3
Fourth growing season	SY0	83.1	55.1	50.2
	SY1	45.8	34.7	47.6
Mean		57.4	41.3	48.4

Summary No. 4. Averaged height (in inches) of tallest seedlings

At end of	Seeded Year	Spruce	Balsam	Birch
Second growing season	SY0	1.60	1.53	3.99
	SY1	1.47	1.69	6.74
	SY2	1.57	1.80	10.73
	SY3	1.56	1.47	14.72
Mean		1.54	1.54	5.32
Third growing season	SY0	3.20	1.90	9.72
	SY1	2.70	1.80	11.01
	SY2	2.54	1.52	13.69
Mean		2.80	1.84	10.55
Fourth growing season	SY0	4.81	2.08	12.26
	SY1	3.18	1.13	13.68
Mean		3.93	1.94	11.87

Summary No. 5. Averaged Height of tallest seedlings by site types

At the end of	Seeded Year	Spruce		Balsam		Birch	
		Site Type		Site Type		Site Type	
		AD	O	AD	O	AD	O
Second growing season	SY0	1.70	1.20	2.18	1.44	6.20	2.98
	SY1	2.03	1.51	1.98	1.18	9.96	3.50
	SY2	1.72	1.39	1.66	1.93	11.27	8.84
	SY3	1.60	1.56	1.34	1.37	18.10	13.60
Third growing season	SY0	3.18	2.98	2.50	.99	8.53	2.94
	SY1	3.56	1.75	1.95	1.95	12.37	11.76
	SY2	2.88	2.46	1.75	1.42	18.70	15.86
Fourth growing season	SY0	5.99	3.11	4.13	1.31	14.19	7.62
	SY1	3.64	3.02	1.56	1.49	19.13	10.56