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Information Report NOR-X-256

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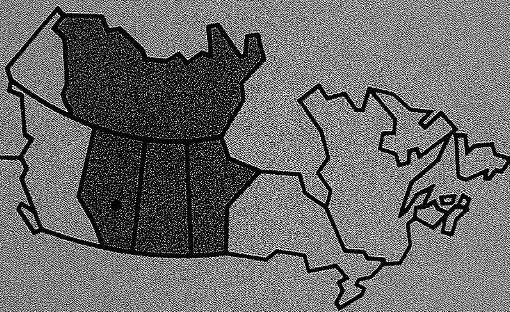

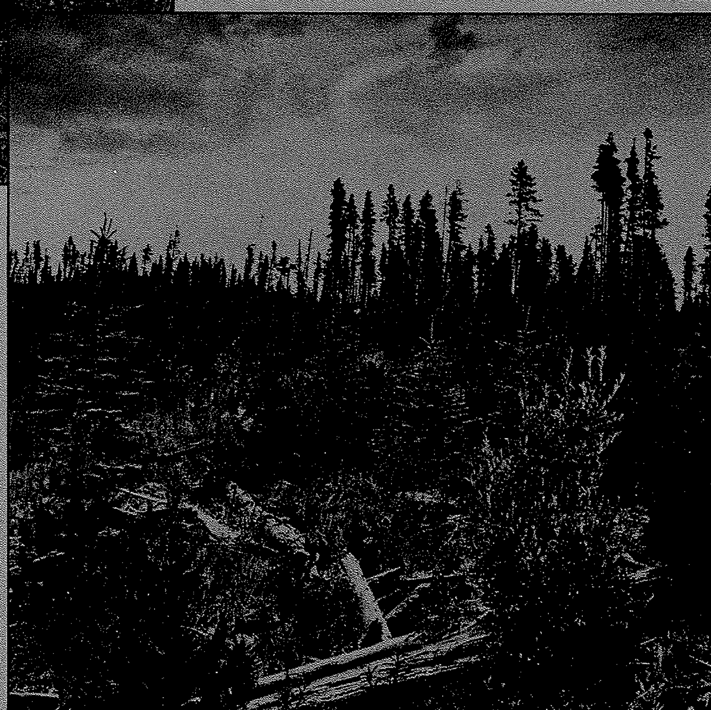

Cover photos:

Left: Original clear-cutting showing stand edge. Right: Eroded stand edge 10 years later.

INFLUENCE OF STAND EDGE ON PLANTED WHITE SPRUCE AND LODGEPOLE PINE

W.D. JOHNSTONE[1]

INFORMATION REPORT NOR-X-256

NORTHERN FOREST RESEARCH CENTRE
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ABSTRACT

The influence of distance from the stand edge on the early growth and survival of planted white spruce (*Picea glauca* (Moench) Voss) and lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) seedlings is reported for a study carried out between 1973 and 1977 on four clear-cuttings in west-central Alberta. The performance of spruce and pine seedlings planted 15, 46, 91, 137, and 183 m from the uncut stand edge was measured over three growing seasons after the year of planting. Because of the influence of natural and artificially created planting microsites, neither seedling growth nor survival could be related to the distance from the stand edge. Cut block size itself did not affect the performance of planted spruce or pine seedlings. In the absence of testing, it should not be inferred that a similar conclusion can be applied to natural regeneration.

RESUME

L'influence de la distance de la lisière du peuplement sur la croissance initiale et la survie de semis plantés d'épinette blanche (*Picea glauca* (Moench) Voss) et de pin tordu latifolié (*Pinus contorta* Dougl. var. *latifolia* Engelm.) a été étudiée entre 1973 et 1977 à quatre emplacements de coupe rase dans le centre-ouest de l'Alberta. La performance des semis plantés à 15, 46, 91, 137, et 183 m de la lisière d'un peuplement non coupé a été mesurée au cours des trois saisons de croissance suivant l'année de plantation. En raison de l'influence de micromilieux de plantation naturels ou artificiellement créés, il n'a pas été possible d'établir un rapport entre la croissance ou la survie des semis et la distance de la lisiere. Les dimensions du bloc coupé n'ont pas influé sur la performance des semis plantés. Il ne faudrait pas déduire, san vérification, que la même conclusion s'applique dans le cas de la régénération naturelle.

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INTRODUCTION

Alternate-strip and patch clear-cutting, which remove all trees of commercial value within a prescribed cutting area, are the most commonly used harvesting techniques in Alberta. The cutting area normally encompasses 16-24 ha but may embrace 200 ha or more. Justification for large-scale clear-cutting is usually related to the economics and efficiency of old-growth stand harvesting (i.e., minimizing road, transportation, and supervisory costs) and second-growth stand management (i.e., minimizing reforestation, protection, and tending costs). Removal of the residual uncut blocks is deferred for up to 20 years or until the cut blocks have been satisfactorily reforested to government standards. When viewed from a distance, however, the adequacy of regeneration is rarely apparent, and the removal of the residual blocks creates the impression that the initially small cut blocks are much larger than the 200 ha mentioned above. In addition to public consternation over the aesthetic impact of clear-cutting (Environmental Council of Alberta 1979), concern has been expressed about the possible adverse environmental impact of clear-cutting on seedling survival and growth (Johnson et al. 1971; Bell et al. 1974).

The present study was initiated in 1973 because of expressed public concern and because of the dearth of information on environmental changes and their effects on seedling growth resulting from large-scale clear-cutting operations. This report describes the influence of distance from the residual (uncut) stand edge, and therefore block size, on the growth and survival of white spruce (*Picea glauca* (Moench) Voss) and lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) seedlings planted in clear-cuttings.

METHODS

Study Location

Four clear-cut blocks were selected for the study on the Forest Management Area (FMA) of St. Regis (Alberta) Ltd., near Hinton, Alberta (Fig. 1). Two cutting blocks (Areas 257 and 262) were located in Compartment VI of the McLeod Working Circle, south of Hinton (15-49-25-5). The remaining two cutting blocks (Areas 566 and 74) were located in Compartment XVI and XIX of the Athabasca Working Circle, north of Hinton (33-53-24-5 and 10-54-24-5), respectively. These blocks were selected because they represent dominant soil types on the FMA.

The dry continental climate of the FMA results in short, cool summers and long, cold winters. The mean annual temperature for the management area ranges from 1 to 3°C, and the mean annual precipitation varies from 510 to 560 mm, with approximately one-third occurring as snow (Hillman et al. 1978). During the summer (May to September), mean temperatures range between 8 and 12°C, mean precipitation is between 350 and 450 mm, and July is the warmest and wettest month (Powell and MacIver 1976). The frost-free period for the FMA ranges from 50 to 100 days, depending upon location (Hillman et al. 1978).

Study Area Description

The soils of Area 257 are predominantly Orthic Gray Luvisols with some Podzolic Gray Luvisols developed on Coalspur-Mercoal soil series under the Robb Association. These soils are developed on a till parent material of Cordilleran origin mixed with some colluvium and are very stony. The area is classed as RBB1-RBB4 on the Hinton map sheet of the Hinton-Edson Soil Survey (Dumanski et al. 1972). Area 257 has a slope of approximately 15%, with a predominantly southeast aspect. Prior to clear-cutting in 1970, the dominant vegetation was a dense 90-year-old stand of lodgepole pine

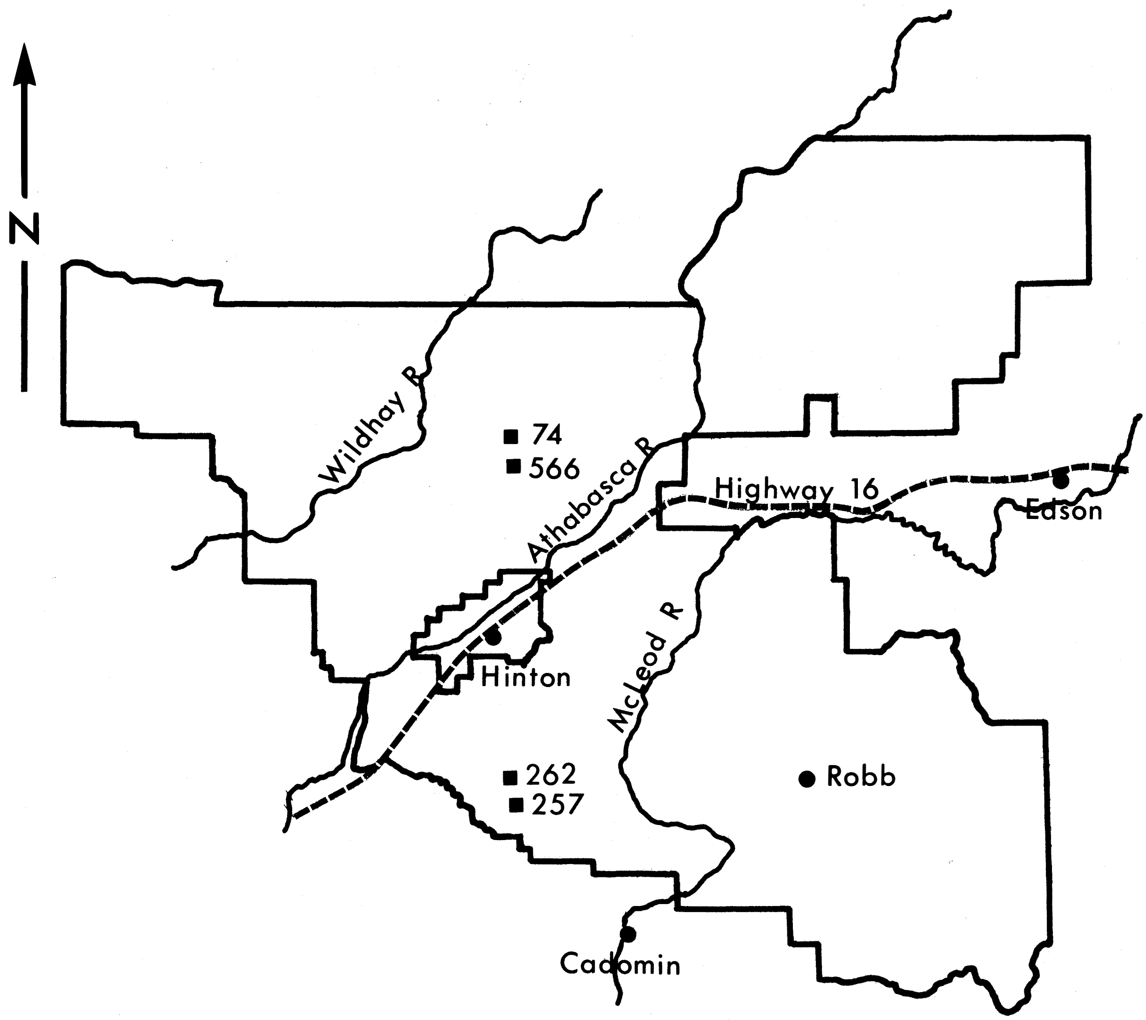


Figure 1. Study area on the St. Regis Forest Management Area near Hinton, Alberta.

with pockets of black spruce (*Picea mariana* (Mill.) B.S.P.). The plot areas were drag-scarified in 1971 and partially hand-cleared of slash prior to planting.

The soils of Area 262 are similar to those of Area 257 but are classed entirely as RBB4 on Hinton map sheet (Dumanski et al. 1972). Area 262 slopes 15-30% and has a southwest aspect. Before clear-cutting for pulpwood in 1970 and drag-scarification in 1971, the dominant vegetation was a 90-year-old lodgepole pine stand. Logging slash was partially hand-cleared from the plots prior to planting.

Soils of Area 566 are predominantly Orthic Gray Luvisols with some Podzolic Gray Luvisols developed on the Hanlan-Wildhay soil series of the Marlboro Association. The soils are developed on medium- to fine-textured Marlboro till of Cordilleran source and are moderately stony. The area is classed as MLB5 on the Hinton map sheet (Dumanski et al. 1972). Area 566 has a 5% slope and a northwest aspect. Prior to clear-cutting for pulpwood in 1969, the dominant vegetation was a 160-year-old stand of white spruce and alpine fir (*Abies lasiocarpa* (Hook.) Nutt.), and there was some lodgepole pine. The plots were drag-scarified in 1970 and then were blade-scarified by bulldozer just prior to planting. This blade scarification removed up to 15 cm of mineral soil, which resulted in drainage problems and created some drier microclimatic conditions.

Area 74 is similar to Area 566 except that its aspect is northeast, the slope is less than 5%, and prior to clear-cutting in 1961 the area was occupied by a 300-year-old stand of white spruce and alpine fir. Here, too, the plots were initially drag-scarified and then blade-scarified prior to planting, resulting in drier microclimatic conditions and subsequently increased grass cover.

Plot Layout

On each study area, five plots were established on each of two transects (A and B) extending from the edge of the uncut stand into the clear-cut area. These plots, which measured 12 x 53 m, were established with their long axes parallel to the stand edge and were centered at 15.2, 45.7, 91.4, 137.2, and 182.9 m (50, 150, 300, 450, and 600 ft) from the uncut stand edge. Each plot was subdivided into five subplots, and each subplot was subdivided into twelve rows (Fig. 2). On Area 257 the aspect of Transect A was slightly different from that of Transect B. Plots 5A and 5B on Area 257 were offset slightly because of a road, as were plots 3 to 5 on transects A and B of Area 262 because of a change in slope.

Planting

The study areas were planted in mid- to late June in 1973 (Areas 257 and 262) and 1974 (Areas 566 and 74). The planting stock were grown in 150-cm^3 Hillson containers (Carlson 1979) for 14 weeks in the greenhouse and 6 weeks in the coldframes. Six rows of spruce and six rows of pine, each row containing 10 seedlings, were randomly assigned to each subplot. A spacing of approximately 1 m was used, although some minor adjustments were made to avoid obstacles such as excessively wet pockets and stumps. A total of 3000 seedlings of each species (300/species/plot) was planted in each area.

Data Collection

Immediately prior to planting, 200 spruce and 194 pine in 1973 and 82 spruce and 81 pine in 1974 were collected randomly from the planting stock. Shoot (top) length and dry weight and root dry weight were measured for each seedling sampled to establish initial seedling sizes.

Immediately after planting, the top height of each seedling was measured and recorded. The location of each seedling was marked with a numbered metal pin. Because the buds had set and no top growth was observed, no further measurements were taken during the year of

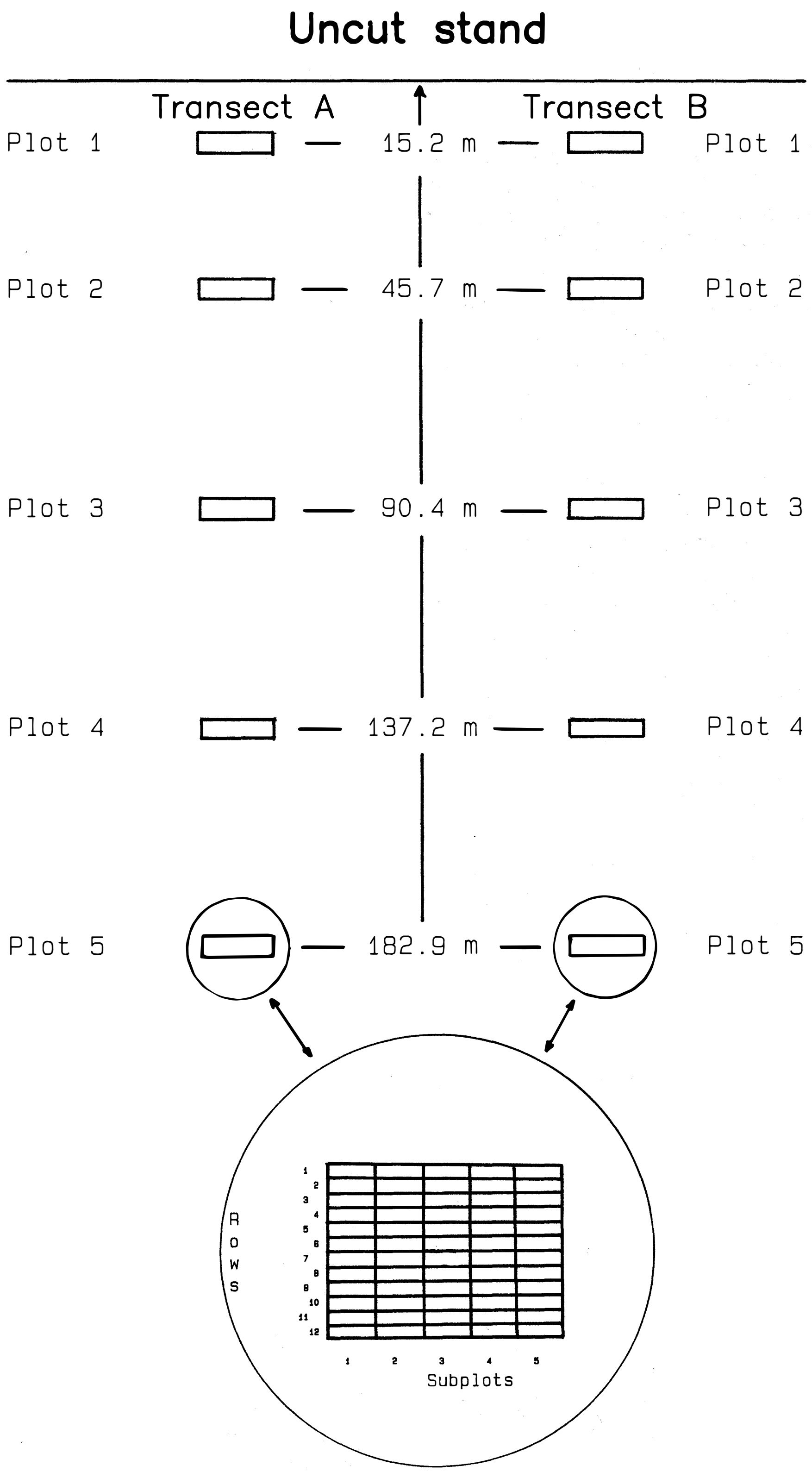


Figure 2. Plot layout.

planting. Samples of the planted seedlings were collected at the end of the first, second, and third growing seasons after planting (Table 1). Each sample was obtained by randomly selecting 4 seedlings of each species from each subplot (4 seedlings per species per subplot per plot per transect per study area). When a selected seedling was dead, the nearest live seedling of the same species was sampled as a replacement. Consequently, a total of 200 seedlings per species per study area was selected at each sampling date. In some instances, because of mortality and previous sampling, particularly during third-year sampling, less than four seedlings of each species were available for sampling in each subplot. The top height and current year's growth of each selected seedling were measured and recorded. The top of each selected seedling was severed at the root collar, stored in a cold room at 2°C, ovendried at 70°C, and then weighed.

During the summer, precipitation, evaporation, air and soil temperatures, and soil moisture were measured on each of the four areas. Observations of seedling condition, including effects of weather and insects, were carried out at each examination date. This information proved useful in interpreting biologically the results of statistical analyses.

Although initiated, an annual assessment of seedling survival was not maintained for the duration of the study. Consequently, it was necessary to determine the level of mortality of the planted seedlings by indirect methods. During the summer of 1979, as part of a separate study, all of the surviving planted seedlings were remeasured. Because the number of seedlings planted and the number of seedlings destructively sampled in each subplot were known, it was possible, using the 1979 tally, to calculate the number of seedlings that had succumbed. This method presupposes that survival of the unsampled seedlings is representative of the entire planted population. Because an adjacent seedling was selected to replace each dead seedling initially selected for sampling, estimates of survival will be conservatively low.

Analyses

Planting Stock Comparisons

Data for top height and shoot and root dry weights of the 1973 and 1974 planting stock, sampled prior to planting, were compared for each species using a paired t-test.

Table 1. Dates of growth, height, and top dry-weight sampling in each study area

	Study area			
Year	257	262	566	74
1974	August 8	August 6-7	-	-
1975	July 23-Aug. 7	July 23-Aug. 6	July 22-Aug. 5	July 22-Aug. 5
1976	July 20-21	July 13-15	Sept. 21-29	Sept. 14-16
1977	-	-	Sept. 7-9	Sept. 9-20

Seedling Growth

Because of differences in planting stock size, planting date, and sampling date, as well as actual physical differences in the study areas, data from each of the four study areas were analyzed separately. Yearly height growth (Y_1), year-end total height (Y_2), and year-end top dry weight (Y_3) data from the seedlings sampled at the end of the three growing seasons after planting were analyzed using analyses of variance (ANOVA) techniques. The analyses were performed on means over seedlings and rows; analyses of variations among seedling and among rows were precluded because of the variation in the number of seedlings sampled at each time period.

The analysis of variance model used (Table 2) is that of a split-plot design wherein the whole-plot treatments (distance, D) are in a randomized complete-block design with two blocks (transects, T), and the split plot treatments (species, S) themselves are blocked (subplots, P) within each whole plot (D). Thus the P/DTM line (i.e., among subplots within each DTM combination pooled over all levels of DTM, where M represents measurement time) eliminates the effect of subplot differences within a given level of D and, through the S x P/DTM line, provides an estimate of the appropriate error for testing S and its interactions with M and D. In choosing this model the assumption was made that the M, T, D, P, and S effects are fixed; therefore, Error (a) was used to test the M and T main effects, Error (b) was used to test the D main effect and the D x M interaction, and Error (c) was used to test the S main effect and all remaining species (S) interactions. Because the species-subplot combinations for each plot could be considered to be in a randomized complete-block design within the more complex overall design, the well-known randomized complete-block estimation technique was used to estimate missing response values. When missing values were estimated, appropriate reductions were made to Error (c) and the total degrees of freedom.

Because initial seedling size could affect subsequent seedling growth (thus affecting the results of the seedling growth analyses), an analysis of covariance was performed on the response variables (yearly height growth, total height, and top dry weight) using initial seedling height as the covariate. The analysis of covariance was limited to the year-end data from Areas 257 and 262, because preliminary analysis indicated that these areas were most likely to be affected by the adjustment for the covariate.

Seedling Survival

For reasons noted previously, data on seedling survival were only available to one given time. Analysis of the percentage survival therefore was based upon means over subplots (P) within distance-transect (D x T) combinations within each study area, and the following randomized complete-block analysis was conducted for each species:

Source of variation	Degrees of freedom
Transect (T)	1
Distance (D)	4
Error (D x T)	4
Total	9

RESULTS

Planting Stock Comparisons

Characteristics of the planting stock sampled before planting in 1973 and 1974 are shown in Table 3. The 1973 spruce planting stock had significantly heavier shoots and roots than the 1974 spruce planting stock because of differences in greenhouse watering regimes; however, observations following on-site storage for several days indicated that there was increased root growth on the

Table 2. General ANOVA (analysis of variance) breakdown for analysis of seedling growth[a]

Source of variation[b]	Degrees of freedom
Measurement time (M)	2
Transect (T)	1
Error (a) (T x M)	2
Distance from uncut stand (D)	4
D x M	8
Error (b) {D x T, D x T x M}	12
Subplots (P/DTM)	120
Species (S)	1
S x M	2
S x D	4
S x D x M	8
S x T	1
S x T x M	2
S x T x D	4
S x T x D x M	8
Error (c) (S x P/DMT)	120
Total	299

[a] For some areas Error (c) and the total degrees of freedom were slightly reduced by missing observations. Data for each area were analyzed separately.

[b] M = measurements (3), T = transects (2), D = distance (5), P = subplots (5), and S = species (2).

1974 spruce seedlings prior to planting. Although similar in terms of shoot length and root weight, the 1973 pine planting stock had significantly heavier shoot weight than the 1974 planting stock. Because each area was analyzed separately, these planting stock differences did not have a confounding influence on the results.

Seedling Growth

Mean yearly height growth, year-end total heights, and year-end top dry weights for each study area are summarized in Figures 3 to 5. The results of the analyses of variance of seedling response for each study are given in Table 4. Response data from Area 566 are shown in detail in Figures 6 to 8 to help illustrate the interpretation of the results of the analyses of variance of seedling response. Because the destructive measurements used in this study necessitated independent random sampling without replacement at each measurement time, the aggregation of successive height increments may not equal the total height for the corresponding measurement period.

Measurement time (M), species (S), and their interaction (SM) significantly affect growth (Y_1) and seedling size (Y_2 and Y_3) (Table 4).[1] This indicates that the differences between species are due to a differential biological response to time. For the first growing season after planting the growth, and therefore size, of the spruce and pine seedlings are essentially the same (Figs. 6-8). This high degree of uniformity during the first growing season, irrespective of species or location, indicates the pre-eminent importance of seedling condition at the time of planting on first-year performance. During the subsequent growing seasons, the growth and size of pine is superior to spruce irrespective of distance, and these differences between species increase with age (Figs. 6-8). These results are as expected, because the juvenile growth of spruce is intrinsically slower than than of pine.

Because D and M rarely interact in any way (Table 4), it appears that the relative effect of M on seedling growth (Y_1) and size (Y_2 and Y_3) is independent of the distance at which the measurement

Table 3. Seedling characteristics before planting

Year of planting	Seedling characteristic	White spruce n	White spruce $\bar{x}$	White spruce $s_{\bar{x}}$	Lodgepole pine n	Lodgepole pine $\bar{x}$	Lodgepole pine $s_{\bar{x}}$
1973	Shoot length (cm)	200	8.09	0.116	194	8.84	0.160
	Shoot weight (g)	200	0.70	0.016	194	0.89	0.024
	Root weight (g)	200	0.16	0.004	194	0.30	0.008
1974	Shoot length (cm)	82	7.96	0.174	81	8.37	0.222
	Shoot weight (g)	82	0.51	0.019	81	0.80	0.032
	Root weight (g)	82	0.10	0.005	81	0.28	0.014

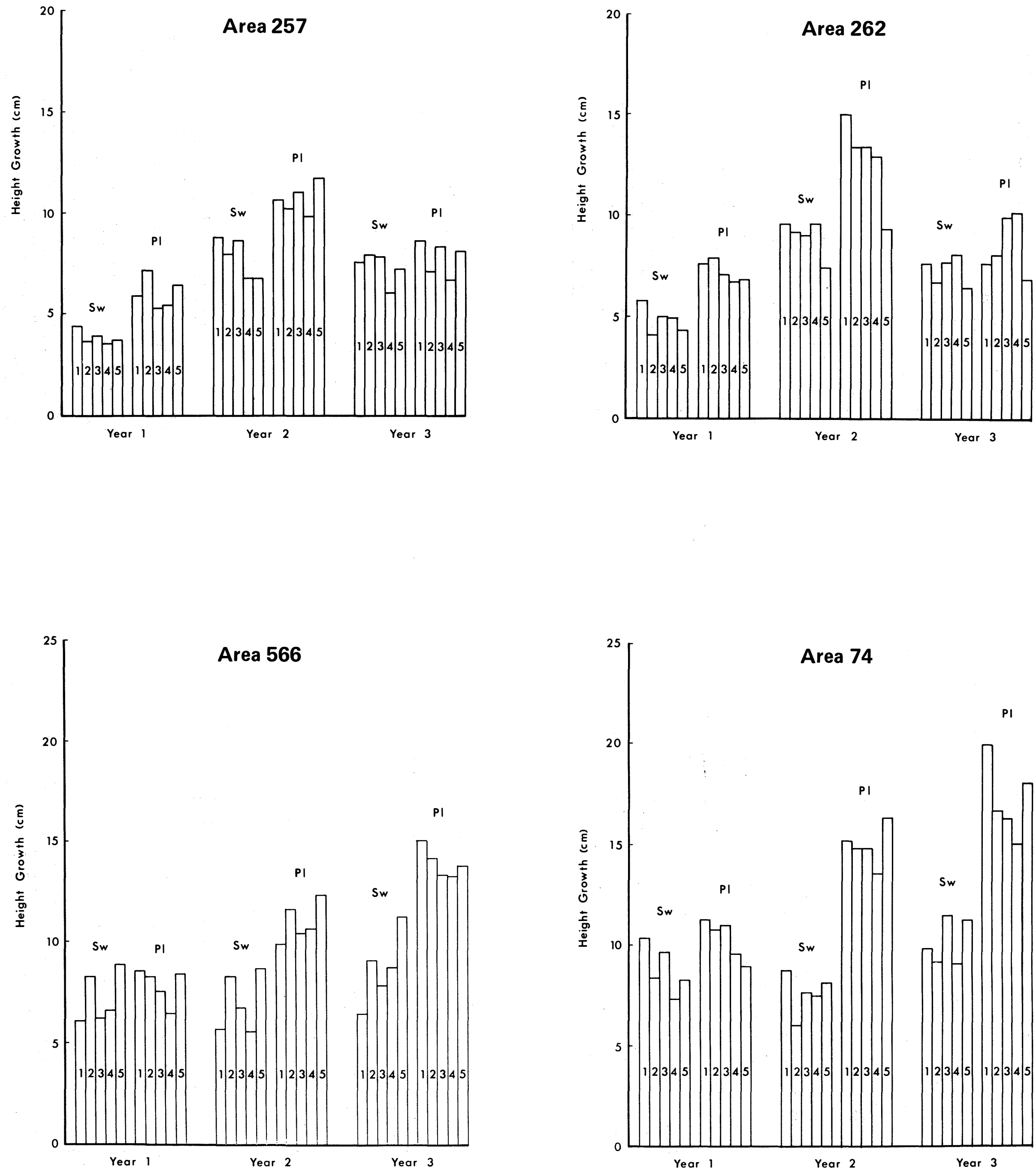


Figure 3. Average yearly height growth of white spruce (Sw) and lodgepole pine (Pl) seedlings planted at different distances (1 = 15 m, 2 = 46 m, 3 = 91 m, 4 = 137 m, and 5 = 183 m) from the stand edge.

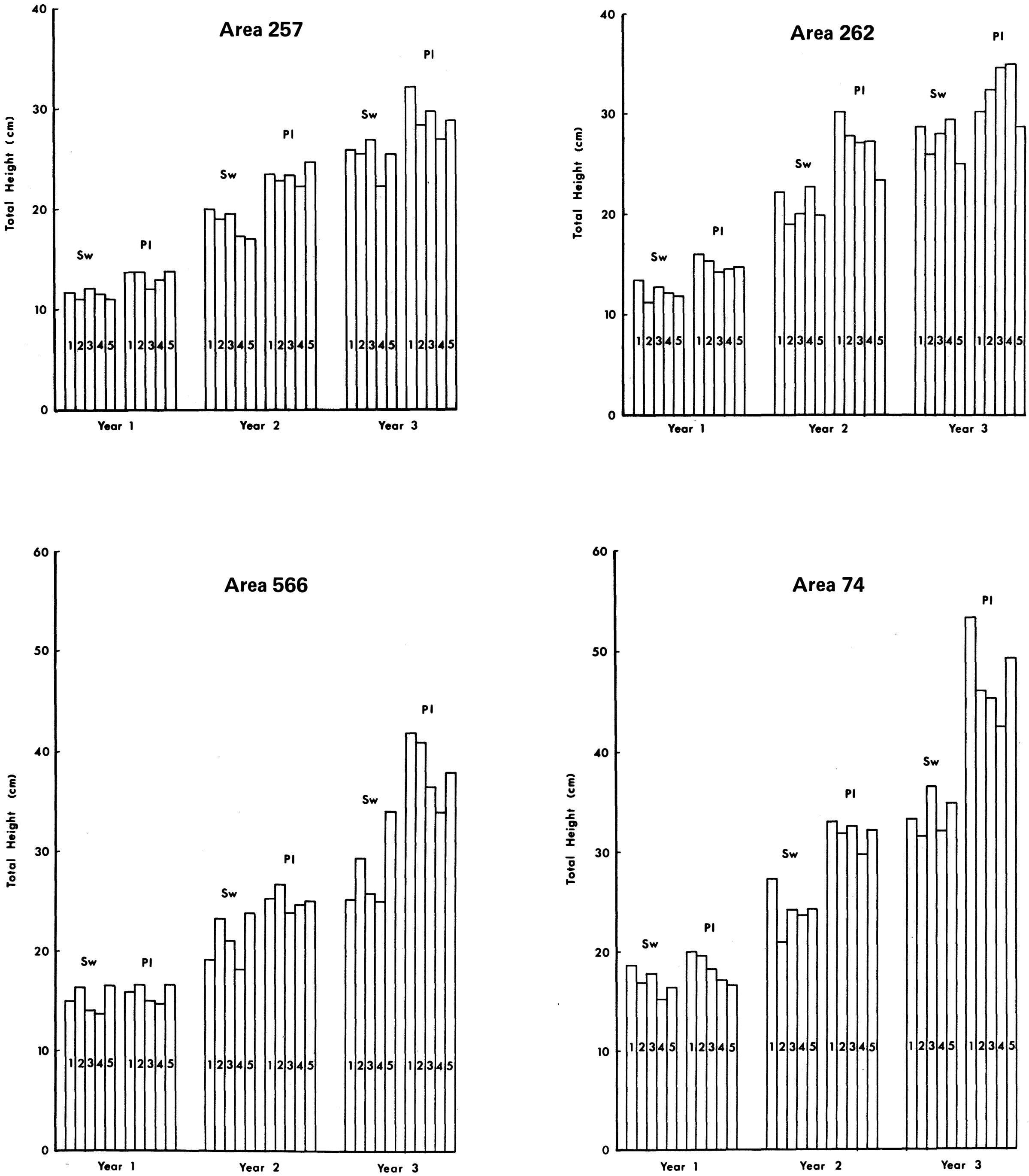


Figure 4. Average year-end total heights of white spruce (Sw) and lodgepole pine (Pl) seedlings planted at different distances (1 = 15 m, 2 = 46 m, 3 = 91 m, and 4 = 137 m, 5 = 183 m) from the stand edge.

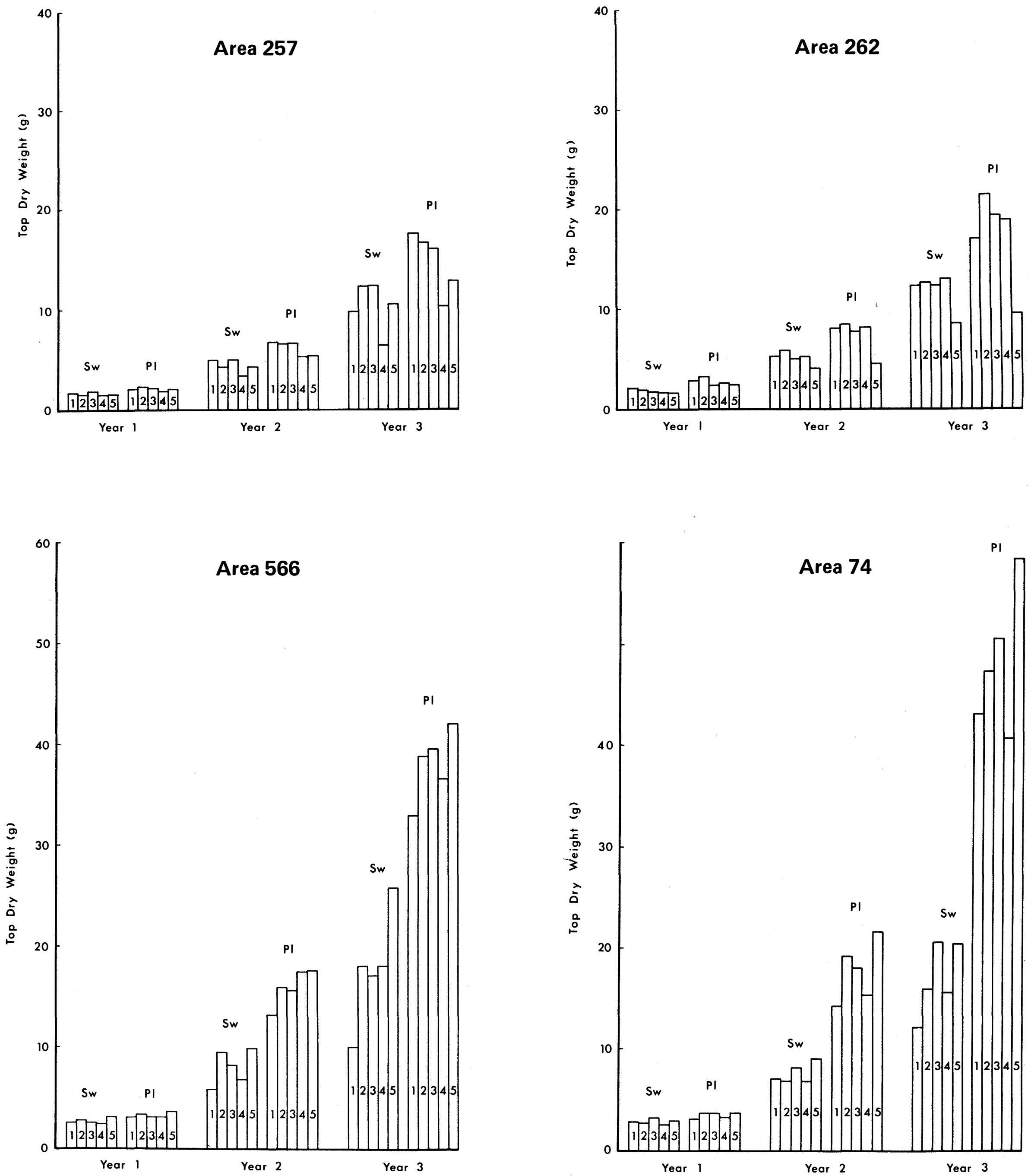


Figure 5. Average year-end top dry weights of white spruce (Sw) and lodgepole pine (Pl) seedlings planted at different distances (1 = 15 m, 2 = 46 m, 3 = 91 m, 4 = 137 m, and 5 = 183 m, from the stand edge.

Table 4. Significance[a] of effects in growth response[b] analysis

Source	Area 257 Y_1	Area 257 Y_2	Area 257 Y_3	Area 262 Y_1	Area 262 Y_2	Area 262 Y_3	Area 566 Y_1	Area 566 Y_2	Area 566 Y_3	Area 74 Y_1	Area 74 Y_2	Area 74 Y_3
M	*	**	**	**	**	**		**	*		**	**
T												
D	*	*	**	*	**		**	**	*		**	**
DM			**									*
P/DTM	**	**	**	**	**	**	**	**	**		**	**
S	**	**	**	**	**	**	**	**	**	**	**	**
SM	**	**	**	**	**	**	**	**	**	**	**	**
SD						*	**	**			**	
SDM								*			*	
ST									**			**
STM												*
SDT	*	**				*	*					
SDTM		*										

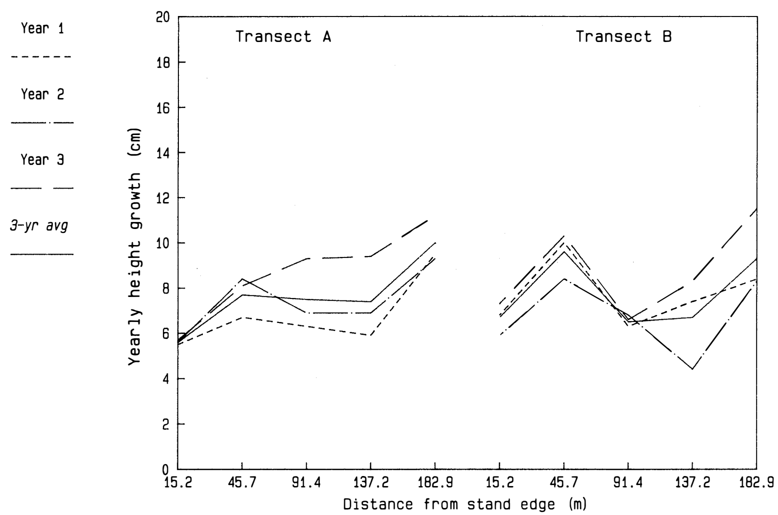
[a] *Significant differences at the p = 0.5 level.
**Significant differences at the p = 0.01 level.

[b] Y_1 = yearly height growth.
Y_2 = year-end total height.
Y_3 = year-end top dry weight.

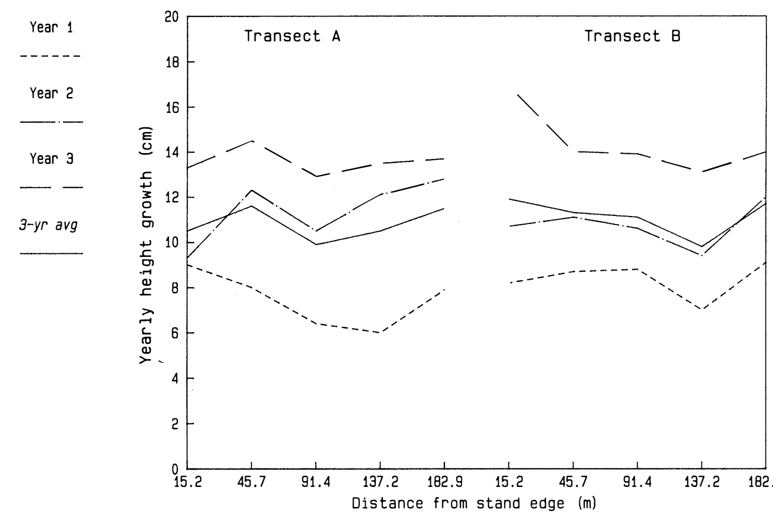
is taken. Figures 3-5 show that the overall M means are quite different relative to the differences among the D means. The general nonsignificance of the DM and SDM lines in Table 4 indicates no significant DM interaction for a given species. Differences that are significant among the M means remain relatively constant over the five distances, even though the individual means, within a measurement time, vary up and down. Thus, the effect of distance (or measurement time) is to raise or lower all of the means by a constant amount so that in any consideration of differences among M means the distance can be ignored, or vice versa.

Although significant differences were detected among distance means (Table 4), the distance means (either within or averaged over measurement times) do not follow any regular trends (Figs. 3-5). This is probably due to differences in drainage, slope, etc. at different distances, which are completely confounded with the distance effects. For example, on Area 566 the plots nearest the stand edge were much wetter than the remaining plots, which may explain the poor spruce performance on these plots. Similarly, the obvious reduction in growth and size of both species at 137 m on Area 257 and at 183 m on Area 262 (Figs. 3-5) are directly ascribable to poorly drained,

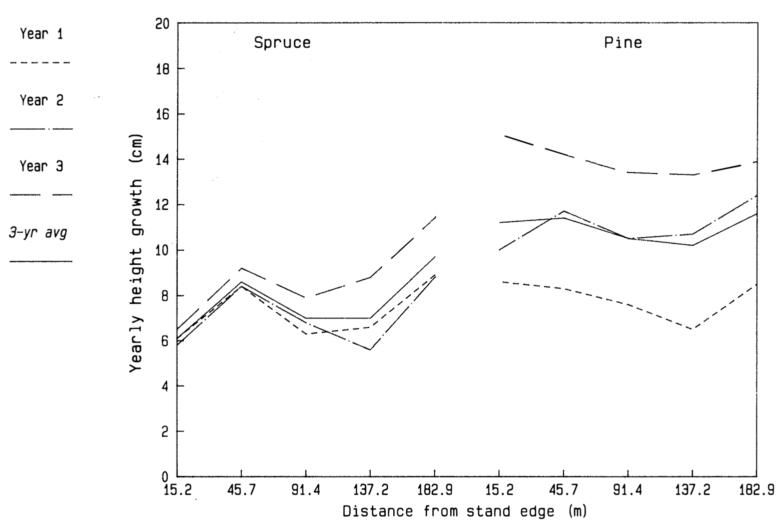
6(a). Spruce seedling height growth on Transects A and B



6(b). Pine seedling height growth on Transects A and B



6(c). Spruce and pine seedling height growth averaged for Transects A and B



6(d). Spruce and pine seedling 3-yr average height growth on Transects A and B

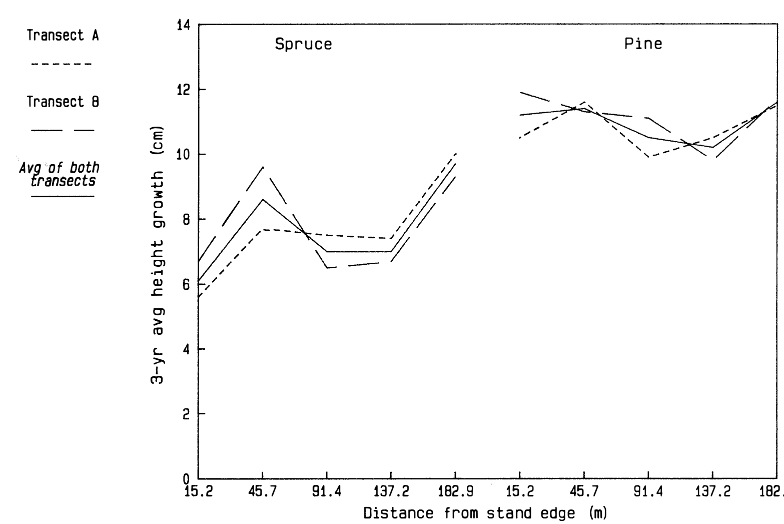
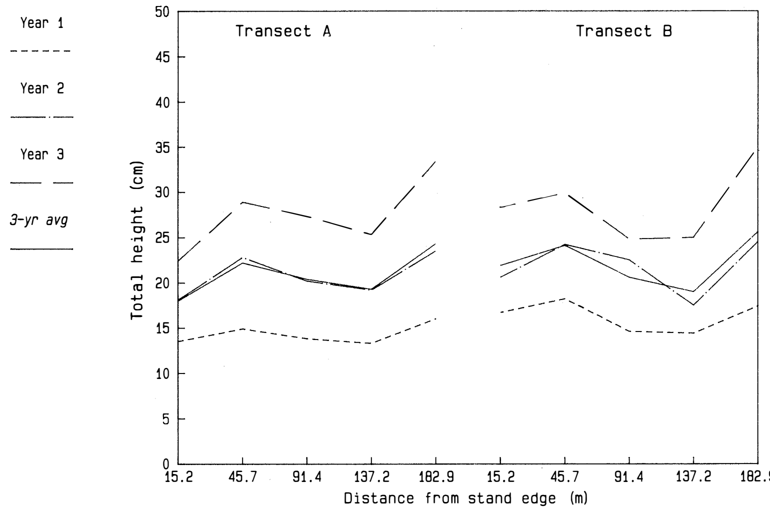
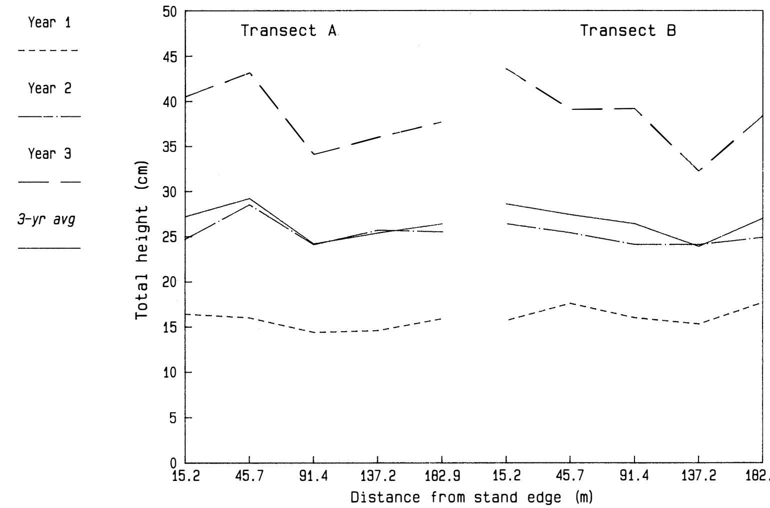


Figure 6. White spruce and lodgepole pine seedling yearly height growth on Area 566.

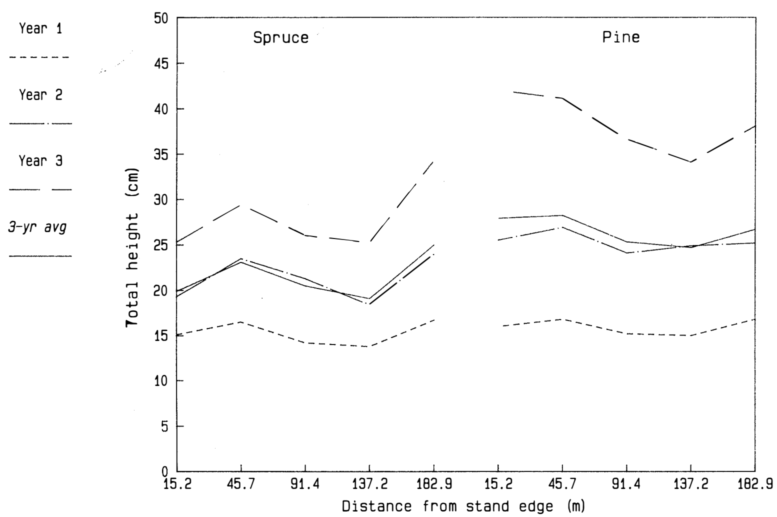
7(a). Spruce seedling total height on Transects A and B



7(b). Pine seedling total height on Transects A and B



7(c). Spruce and pine seedling total height averaged for Transects A and B



7(d). Spruce and pine seedling 3-yr average total height on Transects A and B

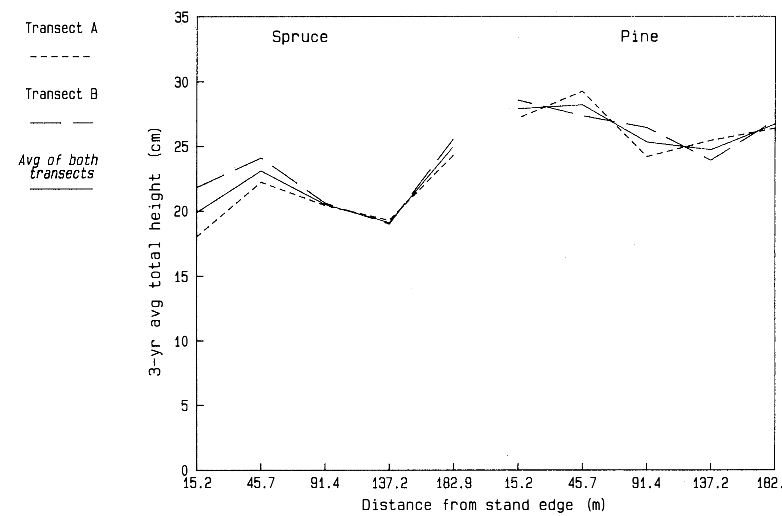
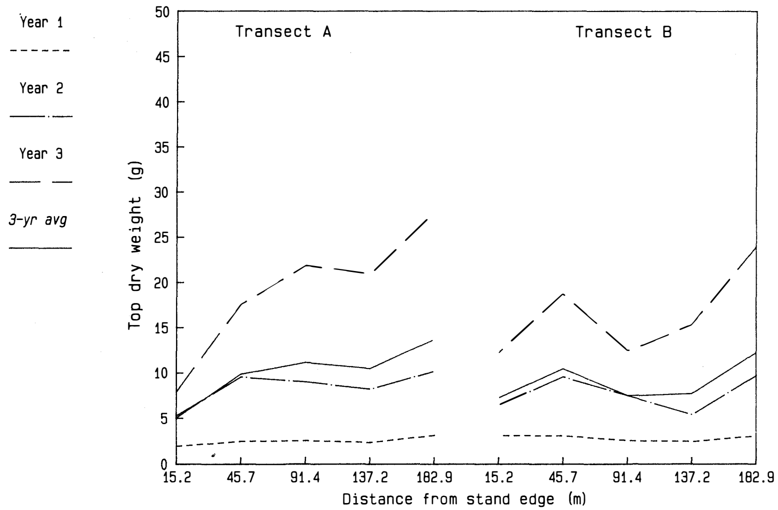
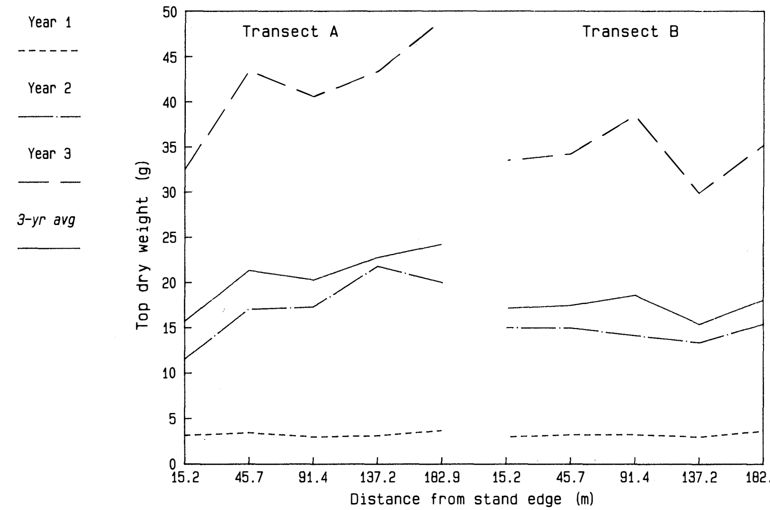


Figure 7. White spruce and lodgepole pine seedling year-end total heights on Area 566.

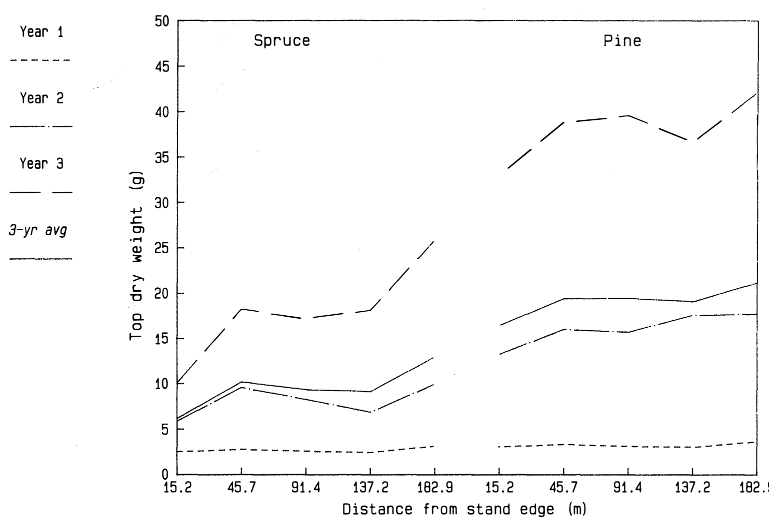
8(a). Spruce seedling top dry weight on Transects A and B



8(b). Pine seedling top dry weight on Transects A and B



8(c). Spruce and pine seedling top dry weight averaged for Transects A and B



8(d). Spruce and pine seedling 3-yr average top dry weight on Transects A and B

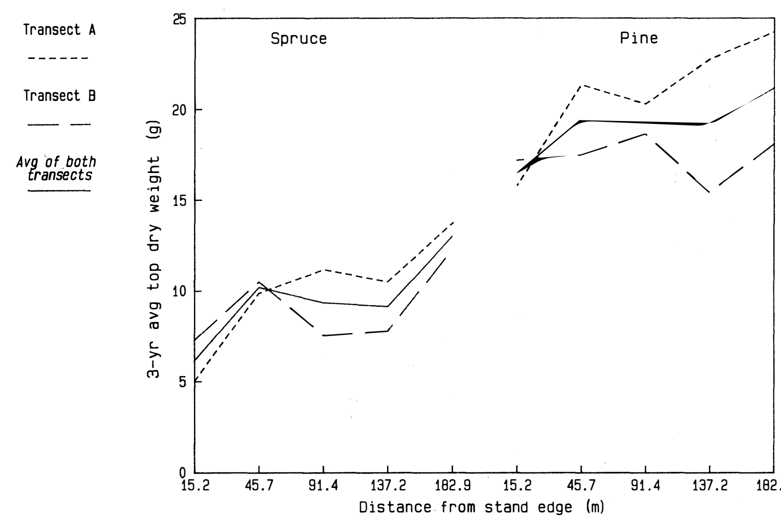


Figure 8. White spruce and lodgepole pine seedling year-end top dry weights on Area 566.

boggy conditions. Variations in planting site conditions occurred naturally throughout the study areas and were also created by the blade scarification of Areas 566 and 74. In addition, there was some confounding of slope with distance on Areas 262 and 257.

The pronounced effects of transect (T) on the form of seedling response to distance for both species are shown in Figures 6d, 7d, and 8d. For Transect A the form seems quite similar for both species, but this is clearly not the case for Transect B. On Transect A both species responded similarly at different distances (or different site conditions). On Transect B different forms of response to distance from stand edge are apparent for both species. Furthermore, both complete-reversal and change-in-rate interactions with respect to transect, particularly for pine on Area 566, are evident in Figures 6d, 7d, and 8d. Because the SDT interaction involves cross-overs, however, these differences average out to produce a nonsignificant transect (T) main effect (Table 4).

The evidence suggests that site differences, both within and between transects, have greatly influenced the results obtained; however, these site differences are difficult to isolate because of the confounding with the distance effect and the probable differential effect of measurement time on species response. These within-area site variations tend to rationalize the otherwise inexplicable, yet statistically significant, effect of interactions involving transects observed in some instances.

Results of the covariance analyses for Areas 257 and 262 tend to support conclusions of the preceding analyses. As before, the M, D, and S main effects and the SM interaction are significant. Because the adjusted means after covariance are almost identical in value to the source means before adjustment, no further discussion of these analyses is presented.

Seedling Survival

For all study areas and both species, there were no significant differences in percentage survival (Table 5) related to distance from uncut stand edge. Further, except for the spruce on Area 257, there were no significant differences in survival between transects. On Area 257, significantly poorer spruce survival was observed on Transect B than on A, and this resulted in the lower mean survival (Table 5) reported for spruce in this study area. The low survival on Area 257 may in part be due to damage resulting from a severe hailstorm that affected this area immediately after planting in 1973. Although damaged seedlings appeared to recover well, overall survival may have been adversely affected. On Areas 266 and 74, the scarification removed the lesser vegetation, which would normally have offered some protection to young seedlings, and reduced the accumulation of snow on these areas. As a result, particularly on Area 566 during the winter of 1975-76, some seedlings suffered from winter drying and top-kill as evidenced by the presence of redbelt injury in 1976. This may account for the lower survival of the taller pine seedlings on the scarified areas (Table 5). The single largest overall cause of mortality was flooding, which directly accounted for about 7% of the mortality observed in the study.

DISCUSSION AND CONCLUSIONS

Concern that large clear-cuttings will create environmental conditions unfavorable to the satisfactory growth and survival of seedlings are not supported by the results observed in this study. Up to the limit tested (over 180 m), distance from stand edge did not influence seedling survival or growth. There therefore appears to be no justification, in terms of growth or survival, for limiting cut-block width to below 400 m (20 chains), except to ensure an adequate seed supply where

Table 5. Seedling survival, by species, for the four study areas[a]

Area	White spruce		Lodgepole pine	
	Mean	Range	Mean	Range
257	65.3	37-88	76.7	54-97
262	81.7	67-95	94.0	82-100
566	87.4	73-97	72.6	70-75
74	88.2	77-98	72.3	69-76

[a] Survival measured in the fall of 1979 (seven growing seasons after planting on Areas 257 and 262, and six growing seasons after planting on Areas 566 and 74).

spruce is being regenerated naturally (Johnson and Gorman 1977), to provide an aesthetically pleasing landscape, or for watershed or wildlife management considerations.

Although significant differences in seedling size and growth were observed at different distances from the stand edge, no consistent pattern in these differences was noted within areas, between areas, or over time. In addition, no statistically significant, consistent improvement in seedling size or growth was noted in the plots adjacent to the stand edge. The rationale for many of these performance differences was directly related to planting site conditions, which were completely confounded with distance in the experimental design of the study. Because the influence of the stand edge on climate extends little beyond the stand's height (Cochran 1969; Hallin 1968; Powell 1971), there is no reason to believe that seedling performance will change dramatically beyond the maximum distance studied.

On all sites, at all distances, and at all times, lodgepole pine outgrew white spruce. The generally good growth of both species of seedlings was mainly attributable to the healthy condition and large size of the planting stock (Endean and Hocking 1973; Walker 1978; Walker and Ball 1981; Walker and Johnson 1980). It should be noted that these seedlings were larger than those currently planted operationally in Alberta. In addition, this good growth performance may be partially due to clear-cutting and the postlogging treatment, which raise soil temperature. Previous studies near Hinton (Endean and Johnstone 1974) and at similar latitudes in the interior of British Columbia (Dobbs and McMinn 1974; Eis 1965) have reported temperatures in undisturbed soils to be below optimum for root development and seedling growth.

No significant differences in seedling survival were found in relation to distance from the stand edge. The high survival is mainly attributable to the high quality of planting stock and the care taken at planting. Frost heaving of seedlings, not uncommon in this locale (Walker 1978), was nonexistent in this study, in part because of planting care. Mortality related to vegetative competition was of little consequence, even on the scarified study areas, where competition from invading grasses was stimulated. Flooding, previously studied in spruce by

Lees (1964), was identified as a major cause of mortality in both spruce and pine in this study. Although boggy microsites occurred naturally in all study areas, additional poorly drained depressions were created in the blade-scarified areas.

From the results of this study it is concluded that large clear-cuttings will not necessarily create an environment sufficiently harsh to hamper the growth and survival of planted pine and spruce seedlings. Local conditions of microclimate, microsite (both natural and man-made), soil type, and elevation are probably of more consequence. Deep scalping on two areas resulted in poor growth on upland sites. Aspect did not appear to be a constraint to the survival and growth of either species. In the absence of testing, it should not be inferred that a similar conslusion can be applied to natural regeneration. Factors such as temperature extremes and dry surface soils that can adversely affect the germination, survival, and growth of natural regeneration may have little influence on planted seedlings. This study does suggest, however, that careful planting of large planting stock may remedy natural regeneration failures in large clear-cuttings.

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