White Spruce Regeneration on a Blade-Scarified Alaskan Loess Soil[1]

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ABSTRACT. Following hardwood removal from a mixed spruce-birch-aspen forest stand, portions of the stand were blade-scarified to encourage natural white spruce regeneration. Six years after treatment the number and height of white spruce seedlings were significantly greater on scarified than on unscarified plots. Whereas 100% of scarified sample plots contained five or more seedlings, 73% of unscarified plots contained no seedlings. Exposure of mineral soil and removal of grass competition are essential for the satisfactory natural regeneration of white spruce. Detailed regeneration surveys should not be considered for white spruce until seedlings are 15 cm tall, typically the fifth or sixth year after site preparation.

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On the extensive, well-drained, micaceous loess-derived soils of interior Alaska, the major tree species, white spruce, quaking aspen, and paper birch, occur as both pure and mixed stands. On good sites, white spruce radial increment at breast height may exceed 0.4 cm annually. Diameters of dominant spruce less than 50 years of age often exceed 40 cm at breast height.

Cost-effective regeneration of white spruce is a major forest management objective. In Alaska, natural regeneration is commonly thought to be most cost effective. Currently, regulations of the Alaska Forest Practices Act (Alaska Adm. Code 1981) requires harvested lands to have, within 10 years, a minimum of 1,235 well-distributed trees per ha which have survived two winters and exhibit growth. Of utmost importance in satisfying the intent of this requirement is ensuring that there is an adequate number of "established" seedlings per hectare.

Securing adequate natural regeneration of many Alaskan sites is difficult because of intense competition from bluejoint, a common grass. Bluejoint often exceeds heights of 1.5 m and forms a dense sod. Various site preparation techniques have been used to secure natural regeneration of white spruce; the key to success is removal of surface organic matter (Zasada et al. 1978) and elimination of intense competition from grass. Zasada and Gregory (1969) and Dobbs (1972) concluded that exposed mineral soil provides the most favorable seedbed for germination and early survival of white spruce. Gardner (1983) found that exposure of mineral soil in the Yukon Territory significantly increased stocking, survival, and growth of natural white spruce seedlings.

In Alaska, however, site-preparation prescriptions must consider the erosive potential of the micaceous, loess-derived loams. Since these soils (Alfic Cryochrepts) readily gully unless preventative measures are taken (USDA Soil Conserv. Serv. 1979), site preparation must minimize soil disturbance. Hence, patch scarification which does not create large areas or long stretches of exposed soil is a realistic option.

Blade scarification to create mineral soil patches has been used on spruce sites in British Columbia since 1956 Dobbs (1972). Zasada and Grigal (1978) report Alaskan patch scarification efforts began in the early 1970s. Wurtz and Zasada (1987) report on blade scarification done in small clearcuts and under a spruce shelterwood in late 1972. Arlidge (1967) reported that mineral seedbeds created through blade scarification lose their receptiveness within three years. Zasada et al. (1978) observed that seedbed and seedling survival conditions on mineral soil near Fairbanks, Alaska, deteriorated significantly by the end of the third growing season. This suggests an optimum 3-year period following scarification for the germination of an adequate number of seedlings.

Jablanczy and Baskerville (1969) described three distinct stages of white spruce seedling development: plumulous, soft-seedling, and hard-seedling. The plumulous stage is that of a new germinant less than 2 or 3 weeks old; no seedlings at this stage are present the autumn following germination. The soft-seedling stage is characterized by slow above-ground growth, lack of strong branching, and intermittent cambial activity. This stage lasts 2 to 3 years on mineral soil under good light conditions, 4 to 5 years in grass communities, and 10 or more years in a moss carpet under mature forest. The hard-seedling stage is the period of accelerated leader growth, distinct apical dominance, regular annual ring production, and lateral extension of the root system. From Jablanczy and Baskerville's (1969) descriptions, the hard-seedling stage is the only stage that is capable of competing with associated vegetation.

Thus, under field conditions, for a seedling to be considered "established," it must reach the hard-seedling stage and can be 3 or more years old. Seedlings that have not reached the hard-seedling stage should not be counted as "established" in regeneration surveys. Surveys conducted before the end of the third growing season can be misleading with respect to "established" seedlings. However, early regeneration surveys are still important as insufficient soft-seedlings indicate a natural regeneration failure.

White spruce regeneration is often a gradual process, influenced by seed crop periodicity and seedbed receptivity. An initial regeneration survey 3 years after site preparation should be considered to determine potential stocking. If sufficient seedlings are not present, then artificial regeneration becomes a consideration. The first detailed survey should not be made earlier than the end of the fifth or sixth growing season as this allows 3 years for seed fall and 2 or 3 years for germinants to develop into hard-seedlings. Supporting this rationale, Zasada et al. (1978) state that the first 5 growing seasons are generally a period of seedling development. Butler (1983) suggests that 5 years after disturbance is appropriate because conifer stocking levels increase rapidly to about 5 years after disturbance and then stabilize.

There should be a measure of seedling performance in addition to number of "established" seedlings per hectare. Operationally, a simple field measurement is needed to assess the progress of regeneration performance. Seedling height is one such measure. Published information concerning height of established natural seedlings of Alaskan white spruce genotypes is lacking.

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Objectives of this research are to document the effectiveness of blade scarification in securing natural white spruce regeneration following hardwood removal from a mixed stand and to determine height growth of seedlings 6 years after treatment. A third objective is to identify, for further testing, a practical regeneration survey schedule.

METHODS

Treatment

An overmature, mixed stand of white spruce, paper birch, and quaking aspen within the Bonanza Creek Experimental Forest of the Tanana Valley State Forest (approximately 30 km southwest of Fairbanks) at approximately 275 m in elevation was selected for partial cutting to remove all merchantable hardwoods and dead and dying spruce. The terrain was nearly level to gently sloping. Breast height age of all tree species was 140 to 155 years. Site index for white spruce (Farr 1967) at breast height age of 100 years was 27.9 m and for paper birch (Gregory and Haack 1964) at breast height age of 50 years was 20.6 m. The hardwood component of the stand was in decline; birch crowns were dying, and aspen had fruiting bodies of white trunk rot.

Original stand composition varied considerably, ranging from nearly pure pockets of each species to various mixtures of spruce and birch. Mean number of stems per hectare was 422; white spruce accounted for 247 stems, paper birch 168, and aspen 7. Fourteen percent of the spruce were dead. Prior to treatment, mean total volume was 197 m^3/ha (58% live spruce, 36% paper birch, 2% aspen, 4% dead spruce). Mean total height for spruce was 33.6 m, for aspen 25.5 m, and for birch 23.2 m. The understory was dominated by bluejoint which in many places formed a sod.

The area was contract logged during winter-spring of 1981. All hardwoods and dead spruce, 42% of the volume (82.8 m^3/ha), were cut and skidded full length. Because most skidding occurred while the ground was frozen and/or snow covered, forest floor disturbance was minimal. Removal of hardwoods and dead spruce created a highly variable pure spruce stand which can best be described as open. Current residual basal area ranges from 0 to 41.7 m^2 and averages 17.00 m^2/ha (standard deviation of 11.0).

Partial removal of the overstory canopy stimulated the grass. The area was scarified with a bulldozer blade in early summer of 1982. The operator dropped the blade randomly and turned back the forest floor/sod to expose mineral soil. Depth of scarified patches typically ranged from 5 to 15 cm. In addition, a mound of "overburden" containing sod, forest floor materials, and mineral soil was created.

A wildfire burned a significant portion of the stand in late spring 1983. Only portions of the stand not burned are included in this study. This reduced sampling opportunities to about 25% of the original 38.5 ha. The 1983 cone crop in the Fairbanks area was the third largest in 14 years (Zasada 1985); thus availability of seed was assured.

Seedling Assessment

During the dormant season of 1988–1989, three sample blocks were located in the stand; within each, 20 scarified patches were randomly selected for sampling. At each sample patch, a pair of 1 m^2 plots was established; one within and one outside the scarified area. Within each plot all spruce seedlings were counted, and heights of the five tallest seedlings were measured to the nearest centimeter. In addition, the height of the tallest seedling was recorded for each scarified patch and for a similar area containing the unscarified plot.

Effectiveness of scarification was determined by comparing seedling numbers on scarified plots with those on unscarified plots. Height measurements were used as an estimate of seedling vigor. Mean height of dominant seedlings within a plot provided an expected average growth rate. Height of the tallest seedling in a patch provided expectations for a crop tree under good conditions.

Statistical Analyses

An ANOV indicated no significant differences between blocks (F = 1.17, P = 0.6823); therefore data were pooled. A preliminary analysis indicated that the difference in seedling density on the scarified plots and unscarified plots was great and that the variances were unequal (Table 1). A Wilcoxon signed rank test (Conover 1980) was used to test for significance.

The tallest seedlings (maximum of five) in each plot were used to compare dominant seedling height. Seedlings taller than 50 cm in unscarified plots were ignored because they obviously predated stand treatment. Heights of 300 seedlings on scarified plots were compared with heights of all (49) seedlings on unscarified plots using a two-sample Student's "t" test. Height of the tallest seedling on each unscarified patch was compared with the tallest on the adjacent scarified patch; 22 pairs of patches were found with seedlings. A two-tailed paired Student "t" test of the mean difference was used to compare effects of treatment on seedling height. Finally, simple regression was used to determine if distance from the nearest "seed tree" had any effect on the number of seedlings in a scarified plot.

RESULTS AND DISCUSSION

Scarified plots averaged 92.75 seedlings per square meter (Table 1) compared to 1.28 seedlings on unscarified plots; the latter includes some seedlings present prior to treatment. The difference was highly significant (P = 0.0000). One hundred percent of the scarified plots had seedlings (mean = 92.75/m^2) whereas only 27% of the unscarified plots had seedlings (mean = 1.28/m^2) (Table 1).

These results support the conclusions of Arlidge (1967), Zasada and Gregory (1969), Dobbs (1972), Gardner (1983), and Wurtz and Zasada (1987) that mineral soil is an excellent seedbed for natural regeneration of white spruce. These results support the hypothesis that it is possible to satisfactorily regenerate white spruce through natural regeneration provided an adequate seed source is present. Data from the Petawawa Forest Experiment Station in Ontario suggest per-hectare stocking levels for white spruce of 1,050 to 1,680 (Stiell 1976); the higher level is preferred for initial stocking to ensure full stocking as the stand develops. Therefore, assuming 1,680 well-spaced, 1 m^2, blade-scarified patches per hectare and similar spruce overstory and site conditions, this study suggests that, after 6 growing seasons, the total number of seedlings per hectare could

Table 1. Summary of results comparing blade-sacrified and unsacrified patches.

	Sacrified	Unsacrified
Seedling density		
Mean number per m^2	92.75	1.28
Standard deviation	52.164	3.179
Plots with seedlings, %	100	27
Plots with Seedling >15 cm, %	92	7
Seedling height		
Mean of dominant seedlings, cm	23.48	9.65
Standard deviation	6.546	9.060
Sample size	300	49
Mean of tallest within patch	31.46	19.36
Standard deviation	7.551	15.774

exceed 150,000 and result in intense competition as the stand develops. Wurtz and Zasada (1987) provide information that the annual diameter growth of seedlings 13 years after site treatment can be increased by 49 to 110% during the first year after cleaning.

Mean height of dominant seedlings on scarified plots was significantly greater than on unscarified plots, 23.48 cm versus 9.65 cm (t = 10.25, P = 0.0000). Ninety-two percent of all scarified plots had mean heights of dominant seedlings (5 per plot) greater than 15 cm. In contrast, mean height of dominant seedlings (1 to 5 per plot) on the unscarified plots ranged from 2 to 23 cm with only 4 (7%) plots having mean heights greater than 15 cm. The poor height growth is only partially attributable to vegetative competition; the low number of seedlings indicates an establishment delay which implicates age as a factor.

Mean dominant seedling height on blade-scarified patches at Bonanza Creek averaged twice the height of 5-year-old seeded seedlings (10.9 cm) reported by Gardner (1983) for alluvial soils in the Yukon Territory. This is most probably due to sampling methods; I based mean dominant heights on the five tallest seedlings per plot whereas the Yukon means are based on all seedlings.

Height of the tallest seedling on 22 paired patches was significantly greater on scarified patches (31.5 cm) than on unscarified patches (19.4 cm) (t = 3.39, P = 0.0028). Thus, despite intense seedling competition, patch scarification provides a better initial environment for crop trees than no scarification.

Seedlings over 15 cm tall appear to be well established and capable of growing: previous season's leader growth commonly was 5–10 cm; many had one distinct branch whorl; needles were robust; and apical dominance and terminal buds were well developed. Most seedlings less than 15 cm did not have well-developed apical dominance, and fewer had a distinct branch whorl. At 15 cm, most seedlings resemble the hard-seedling stage described by Jablanczy and Baskerville (1969). This study suggests that a detailed regeneration survey should be delayed until dominants have reached a mean height of 15 cm; typically, this occurs 5 or 6 years after site preparation on well-drained micaceous loams of interior Alaska.

No correlation (r = 0.32, P = 0.74) was found between seedling density on scarified plots and distance to the nearest seed tree. This is not surprising since the maximum distance of any scarified plot from a seed tree was only 40 m.

The scarification treatment effectively removed the grass sod. Horsetail is now the dominant herb on scarified plots. By the end of the sixth growing season, grass was beginning to recolonize the scarified patches. None of the scarified plots exhibit evidence of erosion.

SUMMARY

Natural regeneration of white spruce following hardwood removal in mixed stands on unscarified sites in interior Alaska, especially where bluejoint forms a sod, will likely fail. Blade scarification removes the grass and provides excellent mineral soil seedbeds for natural regeneration of white spruce. Approximately 15 cm appears to be a threshold height for physiologically "established" seedlings.

Two regeneration surveys appear necessary for intensive management of white spruce: (1) a reconnaissance survey after the third growing season to check for regeneration failure; and (2) a detailed survey after seedlings have reached a height of approximately 15 cm, typically after the fifth or sixth growing season. Such a schedule must now be verified. □

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