NATURAL REGENERATION OF WHITE SPRUCE UNDER SPRUCE-ASPEN SHELTERWOOD, B-18a FOREST SECTION, ALBERTA

by
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Résumé en français

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1. Page 2, paragraph 3 - Last sentence should read:

   In 1959, pretreatment milliacre stocking to white spruce regeneration was 10%.

2. Page 7, Table 3, column 3, row 1:

   For 66 read 16.

ABSTRACT

This report examines growth and survival of white spruce seedlings after scarification under a spruce-aspen shelterwood. In 1959, nine 10-acre plots were scarified with a 10-foot, six-toothed bulldozer blade. Three site groups were sampled - dry upland, moist transition, and wet bottomland.

Scarification produced a receptive seedbed and the residual stand provided an adequate natural seed supply. White spruce regeneration status was raised from 12% mean milliacre stocking in 1959 to 43% in 1963, with 44% stocking on dry, 47% on moist, and 38% on wet sites. Failure of regeneration because of seedbed flooding was common on wet sites, but only 10% of scarified spots on moist sites were affected. Initial seedling mortality was high and was most severe overwinter. Survival improved after the first two growing seasons. Vegetative competition affected seedling height growth on all sites. Mineral soil was the most productive seedbed on scarified areas and rotten wood on undisturbed areas.

RÉSUMÉ

L'auteur analyse la croissance et la survie des semis d'Épinette blanche (*Picea glauca*) après certaines opérations de scarifiage en peuplement d'abri composé d'Épinettes et de Trembles (*Populus tremuloides*). En 1959, neuf lopins de 10 acres ont été scarifiés au bulldozer muni d'une lame à six dents. Trois groupes de stations ont été échantillonnés: collines sèches, stations de transition humides et basses terres très humides.

Le scarifiage rendit le sol propice à la régénération et le peuplement résiduel fournit suffisamment de graines. Le reboisement des Épinettes blanches passa de 12% par milli-acre, en moyenne (en 1959), à 43% en 1963 (i.e. 44% en terrain sec, 47% en lieu humide et 38% en sol très humide). En terrain bas et très humide, la régénération allait souvent mal parce que les graines et puis les semis étaient noyés; cependant, seulement 10% du sol scarifié était inondé dans les stations intermédiaires (humides). Le taux de mortalité des tout jeunes semis s'avérait élevé, surtout pendant le premier hiver. Le taux de survie augmenta après deux saisons de croissance. La croissance en hauteur des semis était partout retardée par la végétation concurrente. C'est le sol minéral qui constituait le milieu le plus propice en terrain scarifié, et le bois pourri en terrain laissé intact.

NATURAL REGENERATION OF WHITE SPRUCE UNDER SPRUCE-ASPEN SHELTERWOOD, B-18a FOREST SECTION, ALBERTA

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INTRODUCTION

Management of spruce-aspen stands in the Slave Lake (Alberta) Forest by partial cutting with individual tree-marking began in 1951. Research into the selection of the most suitable harvest-cutting methods and testing of mineral soil seedbeds for white spruce regeneration were initiated in that year. Scarification consisted in exposing mineral soil by removing the surface organic-soil horizons with hand-tools on small 5-foot-square patches. White spruce[2] (*Picea glauca* (Moench) Voss) germination and survival were compared on exposed and undisturbed seedbeds. Mineral-soil seedbeds gave the best regeneration results (Quaite, 1956; Lees, 1963). In 1952, studies of mechanical seedbed scarification under a range of residual stand densities were initiated. Here scarified strips were bulldozed to expose patches of mineral soil on 40 half-acre plots. Regeneration was successful on scarified patches but failed on the undisturbed and mounded spoil seedbeds (Lees, 1963). Removal of up to 65% of white spruce basal area in the mature mixed spruce-aspen stands resulted in increased growth of residual spruce, with no loss of wind-firmness (Smithers, 1959; Lees, 1963). As few as six parent spruce per acre constitute an adequate seed source (Quaite, 1956). Similar results have been obtained in regeneration and growth studies carried out in the Mixedwood forest section in Manitoba and Saskatchewan. Regeneration trials and a review of machine application in scarification are presented by Jarvis *et al.* (1966). Survival and growth of seedlings is affected by surface drying of the seedbed while the germinant roots are superficial (Eis, 1965), and subsequently by competition from ground vegetation, especially grasses (Waldron, 1966). Seedlings on cultivated seedbeds are better able to withstand limiting conditions of moisture and light (Sutton, 1968).

The study now being reported began in 1959, when more extensive machine scarification was carried out in stands that had been cut over for

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[2]Botanical nomenclature follows Moss (1959).

spruce sawtimber on an individual tree-marking basis in 1953 and 1954. Regeneration after cutting was inadequate. The object of the treatment was to raise white spruce regeneration stocking to acceptable levels and to test mechanical seedbed scarification over a wide range of soil-moisture conditions. The existing uniform shelterwood cutting in the Slave Lake Forest was used and was followed by mechanical scarification to create receptive mineral-soil seedbeds. The investigation then undertaken involved scarification on a range of sites, and support studies of subsequent white spruce seedling survival and growth. Scarification with a toothed bulldozer blade was completed in the summer months of 1959 in co-operation with the Alberta Forest Service. It is proposed to remove the remaining spruce overstory after seedlings are well established on the scarified ground. Unmerchantable trembling aspen (*Populus tremuloides* Michx.) and balsam poplar (*Populus balsamifera* L.) stems remain as a deteriorating nurse stand. This report covers observations made during the early regeneration period 1959-64.

SITE DESCRIPTION

To investigate site-range application of the treatments, three major site groups[3] were sampled: dry upland, moist transition, and wet bottomland. Three homogeneous 10-acre plots were established on each site group. Descriptions of the sites follow:

Dry Upland

These are well-drained[4] sites occurring along ridges and on upper slopes. Stony, sandy loams and clay loams are predominant. Parent material is calcareous. The litter and humus layer (L-H) is shallow, 1 to 4 inches in depth. In a total moisture-regime range[5] from 0 (very dry - sandy aeolian knolls) to 9 (wet - deep bog), these sites lie in the 2 to 3 moisture-regime range. The vegetation is a dry grass-low shrub-herb type. The mean residual stand amounted to 134 square feet of basal area per acre with 31% spruce and 69% hardwoods. Stand age was around 100 years for all species. In 1959, pretreatment milliacre stocking to white spruce was 10%.

Moist Transition

This site group has a moisture-regime range of 4 to 6 occurring on middle slopes and flats and is moderately well drained, often associated with lateral water movement. These deep, well-developed, Grey Wooded soils

[3]Information for physiographic sites follows Duffy (1965).

[4]Horizon nomenclature and soil-moisture status follow usage in Classification of Canadian Soils (National Soil Survey Committee of Canada, 1963).

[5]Moisture regimes after Horton and Lees (1961).

are fine-textured, mainly clay loams and clays. Litter and humus layers (L-H) range from 4 to 12 inches in depth. Ground vegetation is heavy, with abundant shrubs and grasses. Deep moss cover is common under groups of pure spruce. Dense tall grasses, especially *Calamagrostis canadensis* and *Elymus innovatus*, typify these sites.

Mean residual stands on the sample areas comprised 123 square feet of basal area per acre, with 55% spruce and 45% hardwoods. Before treatment, milliacre stocking to white spruce regeneration was 14%.

Wet Bottomland

This group has a moisture-regime range of 6 to 7 on lower slopes and wet depressions, with an extreme of moisture regime 8 where bordering deep bogs. These sites are common in the gently rolling terrain and support vigorous white spruce stands. Soil profiles show very deep litter and humus development (L-H), with layers from 12 to 36 inches in depth overlying a shallow but sharply defined Ae horizon. Below this are gleyed massive clays. The site is poorly drained. Ground vegetation includes abundant grasses, sedges, and horsetails. Residual-stand mean basal area per acre was 124 square feet with 38% spruce and 62% hardwoods. Pretreatment milliacre stocking to white spruce regeneration was 11%.

MAIN TREATMENT

Methods

Scarification

The TD-9 tractor was equipped with a 10-foot scarification blade fitted with six 12-inch teeth of 3/4-inch steel. These teeth were welded below the blade bit against the reinforcing webbing (Figures 1 and 2). Fourteen acres per 8-hour day were scarified. Alternate lowering and raising of the blade created scarified spots of approximately 11 x 15 feet (Figure 3). The blade bit scalped off all surface organic matter and most of the shallow Ae horizon. The teeth penetrated to the Bt horizon, bringing some of the finer-textured soil to the surface. This, it was hoped, would provide a receptive moisture-conserving seedbed having a variety of micro-seedbed types and relative freedom from drainage problems. The cost of the scarification was $10 per acre, which was paid by the Alberta Forest Service.

Site differences had a marked effect upon the ease of tractor operation. The frequency of mineral-soil exposure on milliacre quadrats in 1963 was 29% exposure on dry sites, 24% on moist sites, and 22% on wet sites. Scarification of dry sites proceeded most rapidly, although large boulders occasionally broke teeth from the bulldozer blade. The operation was most costly and least efficient on wet sites, where traction is poor. To reach mineral soil a deep gouge is created, which often fills with water. Characteristically uneven distribution of suitable seedbeds created on these

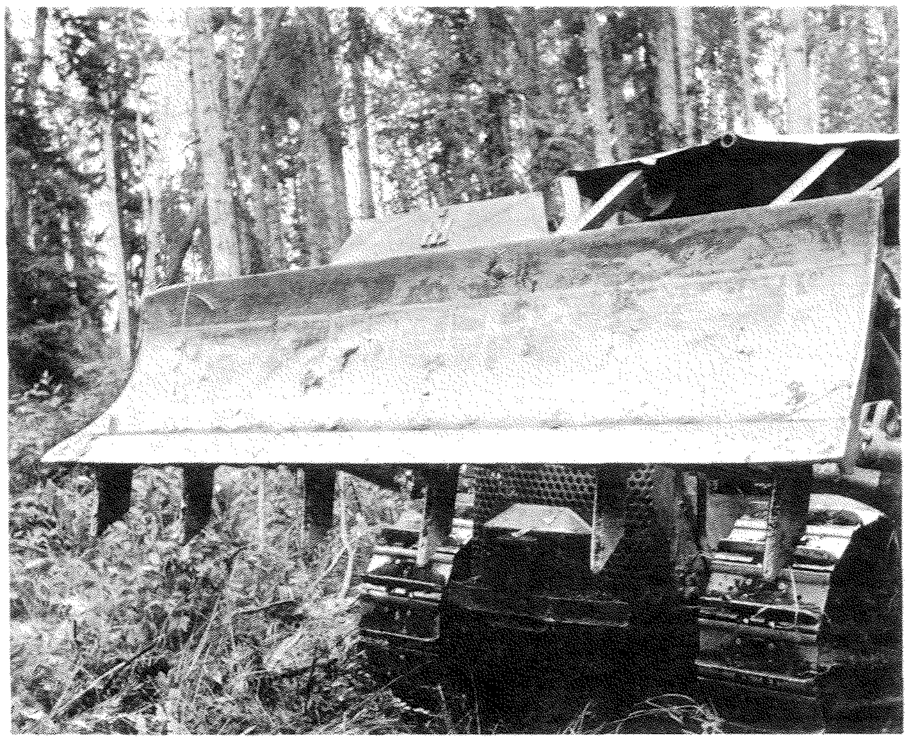

Figure 1 (above). View of tractor and six-toothed blade.

Figure 2 (left). Detail of scarification teeth.

Figure 3. Scarified seedbed - moist site.

wet sites is thus related to the depth of the organic horizons and the difficulties of machine operation. Similarly, damage to residual stems varied with machine maneuverability. Wherever necessary, hardwoods rather than spruce were pushed down. A survey of damage revealed fewer than 10 butt-scarred spruce stems per acre.

Regeneration Assessment

Stocking to white spruce regeneration was assessed in 1963 on 100 milliacre quadrats laid out systematically in two strips across the scarification pattern on each 10-acre plot. Within each strip were units of 10 contiguous quadrats 1 chain apart. On a total of 900 quadrats, data were collected in accordance with the following:

1. Scarification (any quadrat was classed as scarified provided it contained at least one square-foot patch of exposed mineral soil)
2. Stocking to white spruce seedlings
3. Height of the tallest white spruce seedling
4. Leader length of the tallest white spruce seedling
5. Rooting medium of the tallest spruce seedling - five classes
   a) mineral soil
   b) duff
   c) rotten wood
   d) moss
   e) stump

6. Vegetative competition in relation to the tallest white spruce seedling - three classes
   a) light - side competition only
   b) moderate - side and some overtop
   c) heavy - mostly overtop competition

Results

Regeneration status, 1963, is presented in Table 1.

TABLE 1. REGENERATION RESULTS, WHITE SPRUCE STOCKING, 1963*

Site	Percentage quadrats scarified	Percentage milliacre stocking			Average height tallest wS (inches)	Average leader length (inches)
		Overall	Unscarified	Scarified		
Dry upland	29	44	28	85	2.9	1.1
Moist transition	24	47	34	94	2.8	1.0
Wet bottomland	22	38	27	75	2.3	0.8
Mean	25	43	30	85	2.7	0.97

*Based on 900 milliacre quadrats.

On all sites regeneration may now be considered satisfactory. Scarification has raised overall spruce regeneration stocking from 12% in 1959 to a mean of 43% in 1963 (Table 1). The effect of scarification treatment is significant (1% level). Mean stocking on scarified ground is 85% versus 30% on unscarified ground. The differences in stocking values due to site effects alone are not significant. The distribution of regeneration is patchy, however, on wetter sites, because of the poor distribution of scarified seedbeds and because of flooding damage.

Variation in seedling height growth by vegetative competition and site classes is shown in Table 2. The differences in mean leader lengths between competition classes are significant (5% level): light competition, 1.1 inches; moderate competition, 1.07 inches; heavy competition, 0.85 inch. On all sites light vegetation cover allows greatest mean height development. The poorest height growth has occurred on wet sites. Improved soil drainage is reflected in greater seedling growth.

Rotten wood is the most productive seedbed on the unscarified quadrats, especially in the wet areas, where it provides a raised moisture-conserving habitat (Table 3). It also supports 8 to 12% of the tallest seedlings on scarified quadrats. Disturbed duff seedbeds, otherwise very droughty, support 25% of the tallest seedlings on wet sites. Mineral soil is the most productive seedbed on scarified quadrats.

TABLE 2. VEGETATIVE COMPETITION AND HEIGHT GROWTH OF WHITE SPRUCE SEEDLINGS ON SCARIFIED QUADRATS, 1963

	Vegetative competition*	Percentage of quadrats	Average height tallest wS (inches)	Average leader length (inches)
Dry upland	Light	8	2.9	1.2
	Moderate	33	2.6	1.2
	Heavy	59	1.9	0.8
Moist transition	Light	14	3.1	1.2
	Moderate	19	2.9	1.1
	Heavy	67	2.7	1.0
Wet bottomland	Light	12	2.4	0.9
	Moderate	19	2.3	0.8
	Heavy	69	2.3	0.8

*Competition:
Light - side competition only.
Moderate - side competition with some overtop.
Heavy - mostly overtop.

TABLE 3. PERCENTAGE OCCURRENCE OF TALLEST WHITE SPRUCE SEEDLINGS ON FIVE SEEDBED TYPES

Site	Seedbed: Mineral soil	Duff	Rotten wood	Moss	Stump
Dry upland					
Scarified	68	66	12	4	Nil
Unscarified	24	25	39	12	Nil
Moist transition					
Scarified	71	13	8	8	Nil
Unscarified	1	32	49	18	Nil
Wet bottomland					
Scarified	55	25	10	10	Nil
Unscarified	2	9	63	25	1

SUPPORTING STUDIES

Early Survival

A subsample of nine quarter-milliacre quadrats was randomly located on each site. In 1959, 50 white spruce seeds were fall-sown on each quadrat. The original germinants were permanently marked with plastic toothpicks. Survival tallies were made in June and September of 1960, 1961, 1962, and 1963 to assess overwinter and growing-season mortality.

The results are shown for each site in Table 4. The initial germination, 1960, includes the abundant natural seedfall of 1959. The Table 4 values represent only this original seedling population. Overwinter mortality was high for all years. Most of the dead seedlings were found still standing the following spring. Snow mould (*Phacidium* spp.) may have caused this mortality. Major factors contributing to summer mortality are thought to be heat and drought. Damping-off fungi may also have contributed.

Seedbed Deterioration

Each year a further 18 quadrats were fall-sown with 50 seeds on each site group, nine of the quadrats being on the original scarified seedbeds and nine on seedbeds freshly scarified with hand-tools. Survival of germinants was tallied at the start and completion of the growing season each year, and performances on the seedbeds were compared. This control test provided an evaluation of the rate of deterioration of seedbed receptivity on the original scarified ground and a measure of the rate of vegetation encroachment.

The germination shown in Table 5 includes the natural seedfall of each year. Receptivity markedly decreased in 1962, and the very low 1963 germination on the original 1959 scarification indicates that the seedbed is no longer receptive.

Seedbed Flooding

Scarified-seedbed flooding was first observed in the spring of 1960. It was most prevalent on wet sites and of less importance on moist sites. Scarified seedbeds on wet sites, when inundated, remained flooded long enough for the flooding to kill any seedlings under water. On moist sites inundation was intermittent and ended, in all cases, in August. To assess the severity of inundation, all three moist-site plots were selected for survey of frequency and distribution of flooding. All scarified spots on moist sites were visited in 1960 and 1961 at intervals throughout the growing season, and the locations of flooded spots with standing water were mapped. These records are summarized in Table 6. The percentage of scarified spots flooded on each 10-acre plot is presented together with the frequency of inundation.

TABLE 4. SURVIVAL OF 1959 SEEDLINGS* (NINE SEEDSPOT SAMPLES PER SITE)

Site	Total germ. 1960 Num.**	1960 Sept. Num.(%)	1961 June Num.(%)	1961 Sept. Num.(%)	1962 June Num.(%)	1962 Sept. Num.(%)	1963 June Num.(%)	1963 Sept. Num.(%)
Dry upland	1,030	139(14)	110(11)	91(9)	60(6)	56(5)	56(5)	55(5)
Moist transition	2,285	1,599(70)	1,067(47)	954(42)	372(16)	354(16)	243(11)	235(10)
Wet bottomland	1,270	785(62)	488(38)	402(32)	251(20)	222(17)	159(13)	154(12)
Mean	1,528	841(49)	555(32)	482(28)	228(14)	211(13)	153(10)	148(9)

*Permanently marked.

**These figures include natural seedfall, 1959.

TABLE 5. YEARLY SURVIVAL FIGURES FOR WHITE SPRUCE ON ORIGINAL (1959) AND FRESH SCARIFICATION: NUMBERS GERMINATING DURING SEASON, AND SURVIVAL

Site	1961				1962				1963			
	Original seedbed		Fresh seedbed		Original seedbed		Fresh seedbed		Original seedbed		Fresh seedbed	
	Number		Number		Number		Number		Number		Number	
	Germ.	Surv.	Germ.	Surv.	Germ.	Surv.	Germ.	Surv.	Germ.	Surv.	Germ.	Surv.
Dry upland	21	9	14	1	9	4	127	76	Nil	Nil	48	31
Moist transition	57	40	45	29	50	40	281	188	11	9	24	21
Wet bottomland	42	16	64	17	23	15	91	39	6	5	42	25
Mean	40	22	41	16	27	20	166	101	6	5	38	26

TABLE 6. FLOODING FREQUENCY FOR SCARIFIED SPOTS ON MOIST SITES, 1960 AND 1961

	Number and percentage* of scarified spots flooded							Frequency of flooding percentage* of scarified spots			
1960	May 30 Num.(%)	June 13 Num.(%)	June 23 Num.(%)	June 29 Num.(%)	July 6 Num.(%)	Aug. 3 Num.(%)		Not flooded	Less than three times	Three times	Four times or more
Mean	59(13)	19(4)	58(12)	9(2)	14(3)	0(0)		87	8	3	2
1961	June 19 Num.(%)	July 6 Num.(%)	July 10 Num.(%)	July 19 Num.(%)	July 29 Num.(%)	Aug. 3 Num.(%)	Aug. 7 Num.(%)				
Mean	1(0.2)	21(4)	66(14)	12(3)	66(14)	4(1)	1(0.2)	86	9	3	2

*Percentages based on mean density of 465 scarified spots per 10-acre plot.

Seedling survival was examined on a small subjective sample of flooded and control scarified spots. Flooding reduced the mean numbers of seedlings on 20 quarter-milliacre quadrats in 1960 from 62 to 19. Seedlings germinating on the margins of flooded seedbeds survived and grew vigorously. An example of seedbed flooding is shown in Figure 4.

In a subsequent laboratory test, total immersion of white spruce seedlings for 14 days resulted in 100% mortality of 1- and 2-year-old seedlings. A small percentage survived immersion for shorter periods (Lees, 1964b). Since the duration of inundation is most important, areas of deep humus accumulation on wet sites should be avoided in tractor scarification to prevent formation of flooded 'basins.' Flooding, however, is not such a serious threat to seedling survival on other than the wetter areas.

Figure 4. Flooded seedbed.

Seed Supply

An annual estimate of seed supply was obtained ocularly on a half-chain sample strip across each 10-acre plot. The percentage of cone-bearing live crowns was recorded for each spruce stem on these strips. Good seed years occurred in 1959 and 1961. Only a few trees carried cones in 1960, 1962, and 1963. In the years following good cone crops, infestations of cone worm (*Dioryctria abietivorella* Crt.), seed moth (*Laspeyresia youngana* Kearf.), and cone rust (*Chrysomyxa pirolata* Wint.) increased. Larvae affected 30% of the cones sampled in 1962. Estimates of seed supply are presented in Table 7. Regeneration assessed in 1963, therefore, originated mainly in 1959 with some seeding-in in 1961.

TABLE 7. WHITE SPRUCE SEED SURVEY

Site	Mean percentage of live crown with cones				
	1959	1960	1961	1962	1963
Dry upland	16	5 approx	22	Less than 5	Nil
Moist transition	17	"	25	"	Nil
Wet bottomland	18	"	31	"	Nil

DISCUSSION AND CONCLUSIONS

The 1963 regeneration assessment shows that major requirements for successful natural regeneration of white spruce have been satisfied largely by shelterwood cutting and scarification. The overhead residual stand provided adequate seed and a sheltered environment for germination and early survival of spruce seedlings. Scarification provided a satisfactory seedbed, which diminished in receptivity over four growing seasons. In summary:

1. Regeneration stocking in 1963 was satisfactory and amounted to 43% on a milliacre-quadrat basis. Stocking to spruce on scarified seedbeds was 85% and on unscarified seedbeds 30%.
2. The poorest height growth occurred on wet sites.
3. Vegetative competition was heaviest on wet sites where grasses were the most serious competitors.
4. The height growth of seedlings was significantly affected by vegetative competition.
5. Mineral-soil seedbeds supported the greatest proportion of tallest seedlings on scarified quadrats. Rotten wood supported the greatest proportion on unscarified quadrats.
6. Heavy mortality of white spruce seedlings occurred in the first two years after scarification. Survival rates subsequently improved.
7. Overwinter mortality was greater than growing season mortality.
8. The receptivity of scarified seedbeds ceased after four growing seasons.
9. Flooding of scarified seedbeds was most frequent on wet sites and is a serious threat there to regeneration establishment.

The spruce overstory was removed on two of the three plots on each site during the 1966-67 winter logging season. Adequate snow cover protected regeneration against logging operations, and the use of existing (1953) skid trails, haul roads, and millsites minimized damage. The success of this early stage in natural regeneration under shelterwood is supported by the studies of Waldron (1966) in Manitoba. Removal of the residual stand, he recommends, should be carried out at the 2- to 3-year-old-seedling stage and over snow. Release of seedlings from vegetation competition, particularly on moist sites, will be necessary. Further research is needed into the interaction of vegetative competition and site and its effect on regeneration development.

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