CANADA
DEPARTMENT OF RESOURCES AND DEVELOPMENT

WHITE SPRUCE REPRODUCTION RESULTING FROM VARIOUS METHODS OF FOREST SOIL SCARIFICATION

By D. I. CROSSLEY

SILVICULTURAL RESEARCH NOTE No. 102

PLATE 1 — Study area 6 years after logging.

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FORESTRY BRANCH

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Project K-47

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By D.I. Crossley*

INTRODUCTION

The soils of the Subalpine Forest Region of Alberta have generally been derived from high-lime parent materials. With the sudden increase of light that follows clear-cutting, conditions are apparently very favorable to a heavy grass invasion, and a sod definitely unfavourable to re-establishment of the original forest cover soon forms. In order to bring such areas back to forest production within a reasonable length of time, this condition must somehow be changed to one which will permit seedlings to become established. The sod could be broken up in a number of ways, but the use of mechanical equipment suggests the possibility of keeping costs within reasonable bounds. It is recognized that fire may be the natural method, and if so its use should not be ignored. This report is concerned with field trials of both powered equipment and fire, together with the results obtained in seedling establishment at the conclusion of the second growing season.

PROCEDURE

The area selected for investigation is part of the Lusk Creek bench (elevation 4900') on the Kananaskis Forest Experiment Station, which is in the Subalpine Forest Region of Alberta (Halliday, 1937); the topography is gently rolling. Twenty-seven acres of over-mature white spruce (*Picea glauca* [Moench] Voss var. *albertiana* [S. Brown] Sarg.) were clear-cut during the winter of 1940-41; slash was piled but not burned.

Six years after logging, coniferous regeneration was completely inadequate on the cut-over area, in spite of the fact that a marginal seed source of the same stand exists on the windward side. The moderate grass sod was composed chiefly of bluejoint (*Calamagrostis canadensis* [Michx.] Beauv.) and hairy wild rye (*Elymus innovatus* [Beal]). The soil is a loamy podzol on highly calcareous parent material.

For the purpose of the investigation, an elongated 6-acre block was selected on the cut-over area close to the western or windward margin, so that full advantage could be taken of seed dissemination from the bordering stand. The block was divided into 12 half-acre plots, as illustrated in Figure 1. Slash was gathered by hand from the 8 marginal plots and piled

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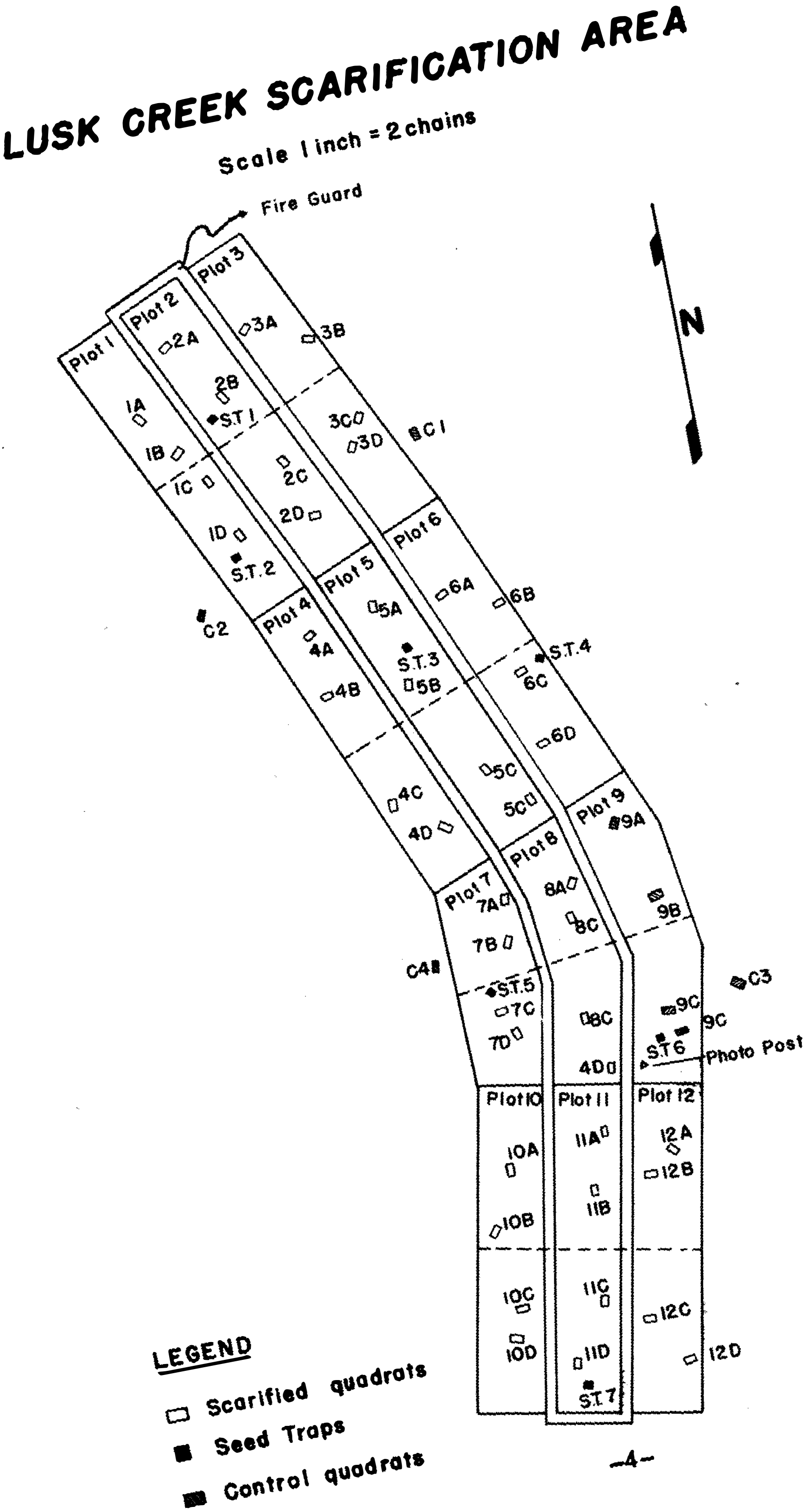
LUSK CREEK SCARIFICATION AREA
Scale 1 inch = 2 chains
Fire Guard
N
Plot 1
Plot 2
Plot 3
Plot 4
Plot 5
Plot 6
Plot 7
Plot 8
Plot 9
Plot 10
Plot 11
Plot 12
1A
1B
1C
1D
2A
2B
2C
2D
3A
3B
3C
3D
4A
4B
4C
4D
5A
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11A
11B
11C
11D
12A
12B
12C
12D
S.T.1
S.T.2
S.T.3
S.T.4
S.T.5
S.T.6
S.T.7
C1
C2
C3
C4
Photo Post
LEGEND
Scarified quadrats
Seed Traps
Control quadrats

Figure

on the 4 centre plots (Nos. 2, 5, 8, and 11) where it was evenly distributed and burned. It is not suggested that such "manicuring" has any place in practical forestry, but it was necessary that the study area be put into a uniform condition in order that subsequent treatments could be compared.

Burning was undertaken during the autumn of 1947, but unfortunately too late to permit completion of scarification. An exceptionally hot and complete burn was obtained on Plot 2 and the south half of Plot 8. The remainder of the strip did not receive as intense heat, owing to a poorer burn, and on it the duff was less completely destroyed. During August of the following summer (1948) the various types of scarification were completed. The difference of one season between time of burning and scarification makes it difficult to compare results.

MECHANICAL TREATMENT

With power supplied in each case by a 45 horse-power crawler-type tractor, the equipment used to scarify the forest floor included the following:

1. Athens type disc-plow
2. Punch packer
3. Bull-dozer blade
4. Growser plates of crawler-type tractor
5. Heavy, green, tree trunks with long branch stubs

The Athens type disc-plow has been strongly advocated for use in the scarification of the forest floor. Eyre and Zehngraff (1948) in the Lake States, and Phelps (1949) in Manitoba have used the implement extensively, the former in red and jack pine and the latter in mixedwood stands of spruce and poplar. Its advantage over the ordinary farm disc in turning over the sod lies in its heavier construction, which enables it to tear up brush and debris and get down to the mineral soil surface, while at the same time absorbing the punishment entailed in working under forest conditions.

The punch packer is a locally designed implement intended to punch numerous small depressions through the duff into mineral soil, at the same time firming the surface soil by its weight. The depressions resulting from the passage of the punches serve as localized individual seed-beds intended to be more receptive to the collection and protection of seed and the germination and survival of seedlings (Crossley, 1947).

Some of the seed falling from above settles in the punched depressions and comes in contact with the mineral soil at the bottom. The chances of escaping destruction by seed eaters are probably better here than on the untouched surface, and the sheltered, humid location more suited to germination and early survival. The implement punches 63,000 holes per acre and is designed to follow minor surface irregularities. Because it rolls freely it is comparatively easy to handle in the woods.

The crawler-type tractor, equipped with a 9-foot blade, bulldozes the duff to one side and bares the mineral soil. Moreover, the passage of the

PLATE 2 – Slash piled on centre strip ready for burning.

PLATE 3 – Slash burned.

growser plates over the scarified mineral soil leaves marked depressions that are a distinct advantage in subsequent germination (Crossley, 1949).

The crawler tractor without blade was utilized in itself as a means of mechanically scarifying the soil surface. By advancing with only one track powered at a time the machine pivots about the locked track. The growser plates on the latter tear off the humus as they swing through an arc and leave the bare, scoured, mineral soil.

Snagged tree trunks have been suggested from time to time as effective and readily available means of scarifying. A green log from a limby, open-grown Douglas fir was used in this investigation. It was 12 feet long, 12 inches in diameter at mid-length, with 8-inch long green branch stubs left on the trunk to serve as scarifying teeth.

Using the scarifying equipment described, either singly or in combination, together with the burning previously completed, the following treatments were undertaken on the study area.

Plot No.	Treatment
1	Athens discing
2	Athens discing after burning
3	Scarifying with locked punch packer
4	Athens discing and punch packing
5	Burning
6	Bull–dozing
7	Scarifying with snagged tree trunk
8	Scarifying with swinging tractor treads after burning
9	Control
10	Punch packing
11	Punch packing after burning
12	Scarifying with swinging tractor treads

Plot 1 was treated with the Athens disc. Sods were well turned for such a rough area and plenty of mineral soil was exposed. The result, however, was a rather open mass of surface debris, and overturned or upended sods and grass, suggesting the possibility of rapid drying, perhaps to the point of heavy seedling mortality. Athens discing after burning on Plot 2 would probably have resulted in a more compact mineral seed-bed if the scarification had been completed the same season as burning. The scarification one year later had to contend with rather prolific grass regrowth and the resulting seed-bed looked very similar to that completed on Plot 1.

The nature of the forest floor on Plot 10 permitted the punch packer to complete its work quite satisfactorily. The punches left distinct depressions through the sod into the mineral soil, and the holes appeared capable of existing as such without caving in and loss of identity. The holes varied in depth from 2 to 2½ inches.

Plot 11 had been previously well burned and the effect of the punch packer was more pronounced than on Plot 10, chiefly because of the

PLATE 4 – Athens type disc-plow drawn by crawler tractor scarifying the forest floor.

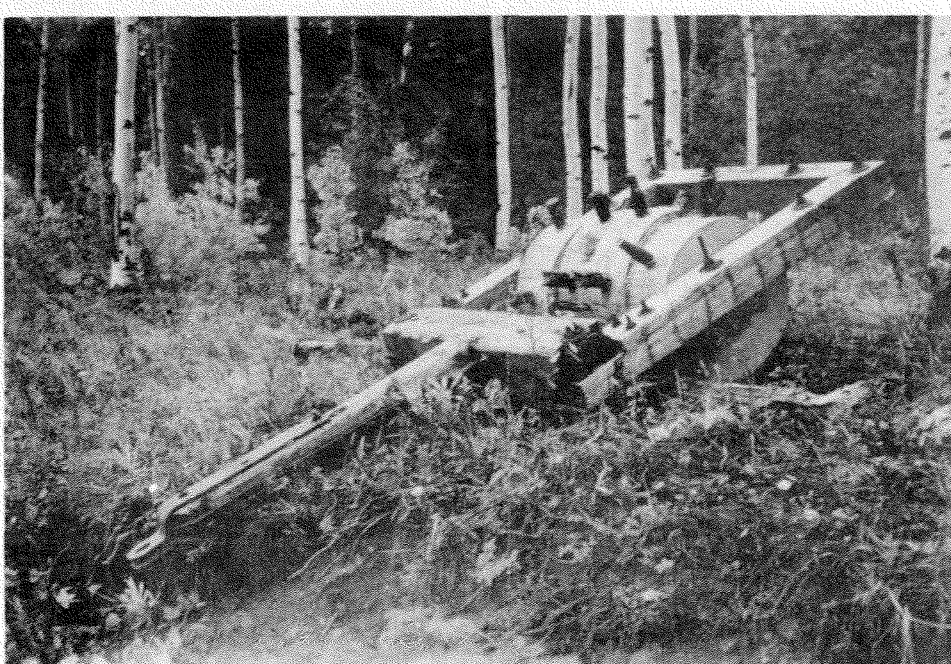


PLATE 5 – View of punch packer showing nature of punches and general construction.

paucity of re-invading vegetation. However it was obvious that the lack of vegetation could also result in rapid loss of hole definition, owing to washing and caving in of the relatively unbound mineral soil.

Athens discing and punch packing were combined on Plot 4. The implements were drawn in tandem with the punch packer following the disc, packing down the rather open mass of soil and debris left by the disc, and at the same time punching depressions into it. The seed-bed appeared to be left in a very receptive condition and promised more successful results than the bed prepared by the Athens disc alone. The combination of implements in tandem however was admittedly awkward to handle in tight locations.

Bull-dozing of the surface duff on Plot 6 was done as completely as possible over the whole unit. By shoving the debris off to the margins, a mineral soil seed-bed was left, crisscrossed with impressions of the tractor growser plates. Torn roots also helped to roughen up the surface.

Plot 7 was scarified by the passage of the snagged tree trunk. Shortly after treatment commenced, it became apparent that the sought-after effect was not being obtained. The trunk rolled from branch stub to branch stub without any individual one getting much chance to dig in and tear the surface of the soil. In an attempt to overcome this a second similar log was cut and chained parallel to the first. This partially prevented the rolling effect, but the branch stubs, even though green and 2-4" in diameter, either broke off or tore out of the trunk. The scarification was completed by driving steel drift pins into the trunks, but this modification soon filled up with debris and the result on the forest floor was chiefly one of smoothing down the grass rather than the sought-after tearing action.

Plot 3 was treated with the punch packer drawn over the area in a locked position. A crow-bar was placed across the frame so that one set of punches caught against it and prevented the rolling motion. The lower set of punches ripped through the soil surface instead of punching depressions into it. As the teeth clogged up with grass and debris, the crow-bar was removed and the implement allowed to roll ahead and clear itself. The scarification effect was better than that obtained from the snagged tree trunks, but this area unfortunately received a light scorching from the adjoining burn that stimulated the growth of grass and made it difficult to obtain the results desired.

Scarification, by taking advantage of the scouring effect on the soil surface of the swinging tractor treads, was undertaken on previously burned Plot 8 and on Plot 12. The sod and humus were skinned off by the pivoting tread, leaving an arc of bare mineral soil scored by the growser plates.

Plot 9 received no treatment other than the manual removal of slash, and serves as a control area. This lifting of the slash may have resulted in sufficient disturbance to encourage regeneration, and for this reason four additional control quadrats were set out on the boundaries of the scarification area (Figure 1).

PLATE 6 – Scarification with the Athens disc-type plow.

PLATE 7 – Scarification by bull-dozer blade, one year after treatment. Note the impressions left by the tractor growser plates.

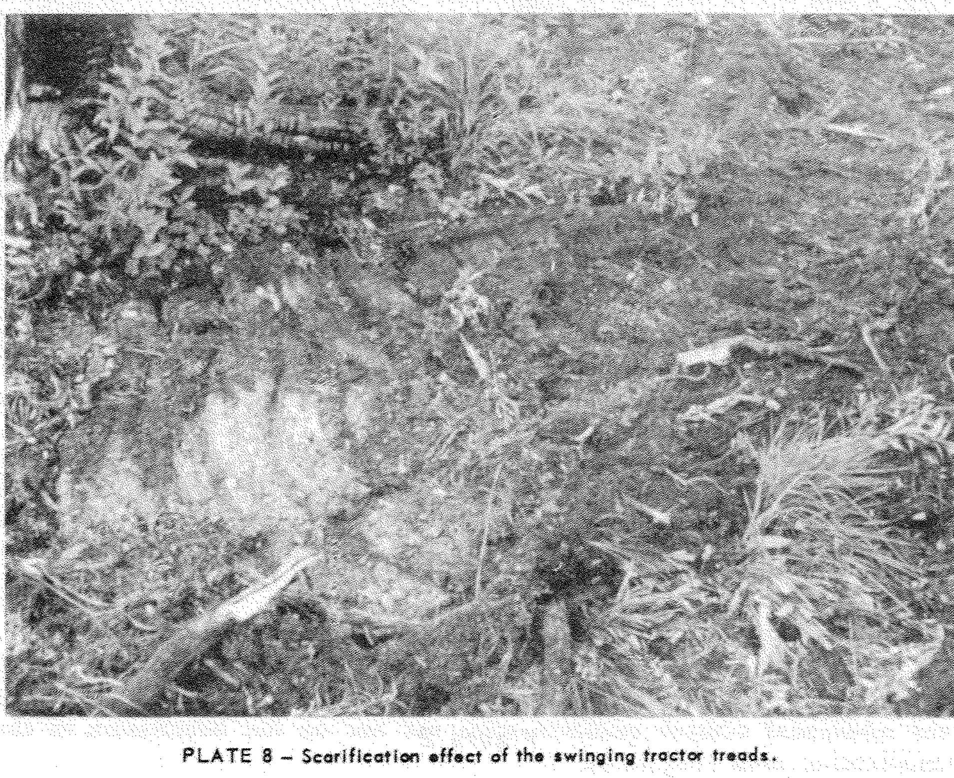
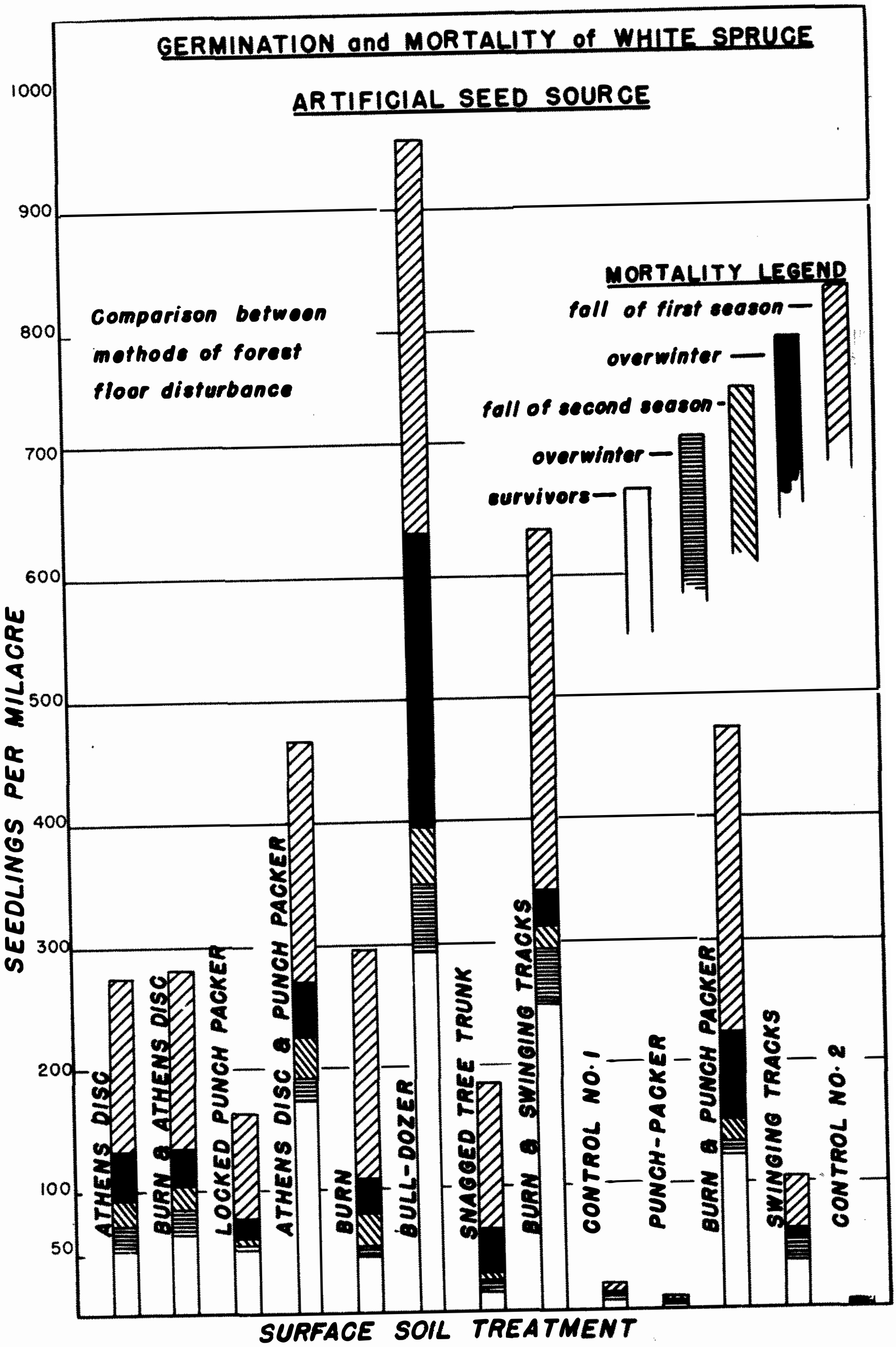


PLATE 8 – Scarification effect of the swinging tractor treads.



GERMINATION and MORTALITY of WHITE SPRUCE
ARTIFICIAL SEED SOURCE
Comparison between methods of forest floor disturbance
MORTALITY LEGEND
fall of first season
overwinter
fall of second season
overwinter
survivors
SEEDLINGS PER MILACRE
1000
900
800
700
600
500
400
300
200
100
50
ATHENS DISC
BURN & ATHENS DISC
LOCKED PUNCH PACKER
ATHENS DISC & PUNCH PACKER
BURN
BULL-DOZER
SNAGGED TREE TRUNK
BURN & SWINGING TRACKS
CONTROL NO·1
PUNCH-PACKER
BURN & PUNCH PACKER
SWINGING TRACKS
CONTROL NO·2
SURFACE SOIL TREATMENT

Figure 2

TABLE 1—Per acre results in the spring of 1951 after 2 seasons.

Plot No. & Treatment	Germination				% Mortality				Survival			
	Artificial Seed Source		Natural Seed Source		Artificial Seed Source		Natural Seed Source		Artificial Seed Source		Natural Seed Source	
	wS	alF*	wS	alF	wS	alF	wS	alF	wS	alF	wS	alF
1 Athens disc	274,500	3,000	0	0	80.3	100	—	—	54,000	0	—	—
2 Athens disc (previously burned)	280,500	1,500	0	0	77.5	100	—	—	63,000	0	—	—
3 Locked punch packer	165,000	1,500	3,000	0	66.4	100	100.0	—	55,500	0	0	—
4 Athens disc and punch packer	469,500	0	10,500	3,000	62.9	—	42.9	0.0	174,000	—	6,000	3,000
5 Burned	297,000	0	1,500	0	84.1	—	100.0	—	47,500	—	0	—
6 Bull-dozer	961,500	0	4,500	0	69.6	—	100.0	—	292,500	—	0	—
7 Snagged tree trunks	186,000	0	1,500	0	90.3	—	0.0	—	18,000	—	1,500	—
8 Swinging tracks (previously burned)	639,000	4,500	18,000	0	60.3	66.6	83.3	—	253,500	1,500	3,000	—
9 Control No. 1	21,000	0	0	0	64.3	—	—	—	7,500	—	—	—
10 Punch packer	9,000	0	0	0	83.3	—	—	—	1,500	—	—	—
11 Punch packer (previously burned)	477,000	1,500	3,000	0	74.5	0.0	100.0	—	121,500	1,500	0	—
12 Swinging tracks	108,000	0	3,000	1,500	59.7	—	50.0	100.0	43,500	—	1,500	0
Control	3,000	0	1,500	0	100.0	—	100.0	—	0	—	0	—

*alF — alpine fir *Abies lasiocarpa* (Hook.) Nutt.

SEEDING

The seed crop on the marginal stand was moderate to light in 1948, and when this condition became apparent steps were taken to apply seed artificially to half of each plot. Each half-acre plot was divided into quarter-acre units (Figure 1) and both received the natural seed-fall. The north unit in each case was seeded with a hand seeder in the autumn of the year with 750 grams of winged spruce seed, or approximately 350,000 seed, germination capacity of which was tested at 55%. Seven seed traps were set out over the area (Figure 1) well in advance of natural seed-fall and resulted in a catch of 74,000 seeds per acre (or 18,500/¼ acre), 24% of which were seeds of alpine fir (***Abies lasiocarpa*** [Hook.] Nutt.), and the remainder white spruce.

METHOD OF STUDY

Four one-third milacre quadrats were laid out on each half-acre plot for the purpose of detailed tallying of germination and mortality. Their locations were selected so that each was located in an area as typical of the general treatment and average site conditions as possible (Figure 1). During artificial seeding, each of the study quadrats was covered with a blanket to prevent it from receiving a haphazard and unknown quantity of seed. After removal of the blanket, these quadrats were carefully broadcast seeded with 2 grams of winged spruce seed (equivalent to approximately 1.38 grams or 630 dewinged seed). They, of course, later received their share of natural seed-fall.

In order to prevent over-winter loss of seed to birds and rodents, each of the ⅓-milacre quadrats was enclosed in a frame covered with ¼-inch wire screening. These screened frames were removed in the middle of June the following year.

Control Plot 9 was subdivided and 2 study quadrats set out on each ¼-acre unit. They were seeded in the same manner as the treated plots. Two of the four additional ⅓-milacre control (C2 and C3), located just outside the boundaries of the treated area (Figure 1), were artificially seeded and screened for rodent protection in a similar manner to all the others.

RESULTS

The study quadrats were tallied for germination and mortality every week of the first (1949) growing season, commencing on June 3 and continuing until September 20. Over-winter mortality was tallied in the spring of 1950 and 1951 and summer mortality in the autumn of each year. The results on both the artificially and naturally seeded quadrats are presented in Table 1. Natural seed-fall may have been insufficient to test adequately comparative seed-bed receptivity, and attention is therefore directed to the results obtained under artificial seeding (Figure 2). Unfortunately, the results of the punch packer treatment on Plot 10 cannot be considered as completely reliable, for reasons noted below. Upon examination of Quadrat 2 in the spring of 1949, it was found that the screened frame had been damaged by porcupines. There was no visible evidence that mice had entered this seed-bed and destroyed any of the seed, but the fact remains that no seedlings appeared. The negative results are included in the average figures for this plot.

A stocked quadrat tally was completed in the spring of 1951, two years after the commencement of germination. Fifty mechanically spaced milacre quadrats were tallied on each quarter-acre unit for the presence or absence of coniferous regeneration, representing a 20% sample. The results are presented in Table 2.

TABLE 2. Stocking results in the spring of 1951, after 2 seasons.

Plot No. & Treatment	Per Cent Stocking	
	Artificial Seed Source	Natural Seed Source
1 Athens disc	78	18
2 Athens disc — previously burned	78	14
3 Locked punch packer	62	10
4 Athens disc and punch packer	86	36
5 Burned	38	10
6 Bull-dozer	90	8
7 Snagged tree trunks	62	12
8 Swinging tracks — previously burned	80	28
9 Control #1	62	14
10 Punch packer	26	16
11 Punch packer — previously burned	74	6
12 Swinging tracks	72	18

DISCUSSION

It is too early in the course of this study to arrive at final conclusions respecting the comparative results of the various methods of soil scarification under investigation. Initial germination after artificial seeding was prolific in all cases, and even the controls were not barren. Two years after germination the surviving seedlings on the study quadrats are in most instances over-abundantly present if one ignores future mortality and considers them established. By Federal Forestry Branch stocking standards (Candy, 1951), which are based on 1000 stocked quadrats per acre, three treatments have resulted in a fully stocked condition (80 – 100%). They are those areas scarified by bull-dozer, Athens disc with punch packer in tandem, and swinging tractor treads after previous burning. Seven treatments have resulted in well-stocked stands (60 – 79%) and only two, the punch packer and the burn, present an under-stocked condition (20 – 40%) at the conclusion of the second year. While the cleared control area is 62% stocked at this time, the seedlings themselves do not present the healthy, thrifty appearance of the majority of the seedlings on the treated areas. The untouched control area was not tallied for per cent stocking since it was not artificially seeded.

Unless one remembers that the ⅓-milacre study quadrats were protected from seed loss prior to initial germination, the large numbers of surviving seedlings are apt to be misleading. These figures do not represent the true picture on the remainder of the area left unprotected, since the initial loss of seed to birds and rodents greatly reduced the possibility of seedlings appearing. The study quadrats serve the sole purpose of providing for a comparison of the germination and survival potentials of variously prepared seed-beds when extraneous factors are as far as possible eliminated.

No attempt was made to establish the cause of death in the case of the individual seedling. Surface heat, drought, competition, smothering, damping-off fungi, needle rust fungi, and insects are taking a steady and heavy toll, but where the mineral soil is bared, soil heaving in the spring has been the greatest single cause of seedling mortality. Loss due to this factor can be related to destruction of soil cover.

Scarification results in the removal of the insulating blanket of forest floor duff and, until the reinvading vegetation has had sufficient time to replace this layer, fluctuating spring temperatures have every opportunity to act on the surface soil. Since the result of the bull-dozer treatment is to completely remove this surface material, the effect of soil heaving was particularly noticeable. On this area it was estimated that 75% of the over-winter mortality in the first two years was due to this cause, the seedlings in most cases being completely uprooted and lying on their sides. As time passes, the insulating blanket of vegetative debris will be effectively rebuilt, and the seedlings themselves will ramify their roots and obtain a stronger and deeper grip on the soil. It is already quite obvious that where the reinvading vegetation is the heaviest, loss of seedlings due to soil heaving is the least. A previous investigation (Crossley, 1951) suggests that such loss diminishes very rapidly after the second spring. While the bull-dozed treatment exhibited this form of seedling mortality most markedly, it existed in all treatments wherever any amount of mineral soil was bared and vegetation destroyed. For example, it was generally heavier on those treatments which embraced a burn, particularly if the burn had been intense (Plots 11 and 8) and therefore presumably more destructive of the soil cover and the binding rootlets than a light burn.

Remarks on the effect of the punch packer are confined chiefly to results on Plot 11, which was heavily burned before receiving the mechanical treatment. The results on Plot 10, which did not receive the preliminary burn, were very poor, and not enough seedlings appeared to warrant drawing conclusions on their behaviour. Since germination on Plot 11 was generally confined to the punched depressions, they obviously provided a more favourable seed-bed than the immediate surrounding surface. In several instances there were as many as 12 seedlings growing in each depression. Mortality, however, was quite high among these seedlings, chiefly owing to the smothering effect of debris drifting into the depressions before the seedlings had developed sufficiently to get their growing tips above ground level. It is felt that the punches were too long and resulted in too deep a hole, and much better results might be obtained by cutting them down to half length.

The smothering effect of leaf and needle litter and decaying grass was most pronounced on areas treated with the Athens disc. In the spring of the year, many seedlings were difficult to find amongst this debris and often exhibited a white mold. By the following autumn it was usually these molded seedlings that had succumbed. The irregularly upheaved seed-bed resulting from the passage of the Athens disc apparently provided pockets and crevices that encouraged collection and accumulation of debris. It appears significant that such accumulations were not nearly so evident on the more compacted area punch-packed after Athens discing and the resulting seedling mortality has been considerably lighter (Table 1).

On the burned plot, seedling mortality appeared to be greatest where charcoal was thickest. It is possible that the heat-absorbing properties of the black debris raised surface temperatures to lethal magnitudes. The same effect was noted on the plot that was burned and punch-packed. Seedlings that appeared on the undisturbed surface between punched-out depressions succumbed rapidly. The remaining 2 plots that received a mechanical scarification after burning either had the burned debris well mixed with the surface soil (Athens discing), or scraped off (swinging treads).

The variable results obtained on the areas that were seeded naturally in what turned out to be a light seed year emphasize the necessity of confining the practical application of this type of artificial soil treatment to years of good to abundant seed crop. In years of moderate seed-fall, scarification could possibly be undertaken if provision were made to control loss to rodents by taking advantage of lows in their population cycles, or by controlling their numbers by poisoning. While in this investigation precautions were taken to prevent loss of seed after it reached the seed-bed, no control was undertaken of the squirrel and bird population that destroyed seed before it left the tree.

CONCLUSIONS

From the results obtained to date it is apparent that the scarification of the forest floor on a non-reproducing cut-over area effectively increases its receptivity to spruce regeneration. The more completely the mineral soil is bared and compacted, the better the results appear to be.

While all treatments resulted in a great number of seedlings under conditions where the seed was protected against loss, such artificial conditions have no practical field application. Recognizing heavy seed loss as a normal field condition, it is obvious that only the most receptive seed-beds can absorb it and still result in an adequate, established stand. The poorer the seed crop the more important seed-bed receptivity becomes, and it must be recognized that good seed crops are the exception rather than the rule.

SUMMARY

In 1947, on the Kananaskis Forest Experiment Station in Alberta, a study was undertaken to investigate the use of fire and of various mechanical methods in the scarification of the forest floor, in an effort to induce the regeneration of white spruce on inadequately restocked cut-over areas. Eleven methods or combinations of methods of soil scarification were adopted during the summer of 1948. Initial germination was in all cases adequate and in some cases remarkably abundant. Two years later the intervening mortality had wiped out the regeneration on the untouched control and reduced the numbers on the treated areas considerably, but in spite of this, three of the scarification methods have resulted in fully stocked stands, seven are well stocked, and the remainder understocked.

The investigation will be continued until final survival is established.

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