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THE EFFECT OF VARIOUS SEEDBED TREATMENTS ON THE GERMINATION AND SURVIVAL OF WHITE SPRUCE AND LODGEPOLE PINE SEEDLINGS

by
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CORRECTION to Technical Note No. 63

Please correct your copy of Tech. Note No. 63 by R.F. Ackerman entitled "The Effect of Various Seedbed Treatments on the Germination and Survival of Lodgepole Pine Seedlings" as follows:

Plate 1 belongs with the legend for Plate 2

Plate 2 belongs with the legend for Plate 1

Figure 3 A & B should appear on page 13

Figure 4 A & B should appear on page 16

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The Effect of Various Seedbed Treatments on the Germination and Survival of White Spruce and Lodgepole Pine Seedlings

(Projects K-59 & K-65)

by

R. F. ACKERMAN[1]

INTRODUCTION

It is generally accepted that available moisture can be one of the most important factors in the germination and survival of forest tree seedlings. The importance of variables, such as the nature of the seedbed and the competing vegetation, in influencing the level of available moisture has been investigated by many authors. Included among these are Barr 1940; Craib 1929; Haig 1936; Kozlowski 1949; Lane and McComb 1948; Lutz 1945; Moore 1926; Pearson 1930, 1931; Reed 1939; Rowe 1955; Toumey and Kienholz 1931.

This investigation was initiated in 1950 by D. R. M. Scott (former research officer, Alberta District Office) to determine the relative importance of unincorporated organic material, lesser vegetation, and root competition of a residual stand in controlling the survival of western white spruce (*Picea glauca* (Moench) Voss var. *albertiana* (S. Brown) Sarg.) and lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) in the Subalpine Region of Alberta.

The investigation consists of two independent experiments. Although the experimental designs and analyses are identical, experiment 1 concerns only spruce while experiment 2 includes both spruce and pine. In addition, the two experimental areas vary considerably in site and stand conditions.

METHODS AND MATERIALS

Description of the Area

Both experiments were conducted on the Kananaskis Forest Experiment Station (115° 10′ W., 51° 0′ N.), located within the Subalpine Forest Region (Halliday 1937).

Experiment 1 is located at an elevation of 4,800 to 4,900 feet, on the lower slopes and bottom of a small protected valley off the main Bow River Valley. The forest cover consists of a 250-year-old spruce-fir stand which had undergone a partial cut in 1949 by which 55 per cent of its 25,000 ft.b.m. per acre was removed (Plate 1).

This area is typical of the better sites to be found in the Subalpine Region. Most of the valley floor is covered by glacio-fluvial deposits weathered into a calcareous brown podzol. A typical soil profile would reveal a moss cover, 5 inches of mor humus over silt to sandy loam over coarse gravel. The prevailing west wind of the area is a definite desiccating agent, but in this particular secondary valley desiccation is countered by the effect of slow-moving ground night air and the accompanying high relative humidity (MacHattie 1954).

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The soil of some of the plots of experiment 1, those located in the valley bottom, has some of the characteristics of a *wiesenböden*. Soil moisture is more than adequate and in some cases organic material may reach a depth of 12 inches.

Experiment 2 is located at an elevation of 4,600 to 4,700 feet, on a level bench above the main Kananaskis River Valley. The present forest cover consists of an 80-year-old stand of lodgepole pine which was thinned in 1950 (Plate 2).

A typical soil profile on experimental area 2 would reveal a calcareous grey podzol with ½ inch to 1½ inches of mor humus over loam over clay loam. This site is also subject to the desiccating effect of the prevailing winds but does not have the advantage of good night recovery.

Contrasting the sites of experiments 1 and 2, the differences of particular importance are:

1. Moisture—the site of experiment 2 is considerably drier than that of experiment 1. Both the abundant soil moisture and the high night relative humidity of area 1 contribute to this difference.
2. Depth to mineral soil—the organic material of area 1 has a depth of 5 to 12 inches while the organic material of area 2 has a depth of ½ inch to 1½ inches.
3. Vegetation—the minor vegetation is normally more luxuriant on the richer site of experiment 1. In addition, the response of the vegetation to opening of the stands was more pronounced on area 1.

Plate 1. General view of the site of experiment 1.

Plate 2. General view of the site of experiment 2.

Treatments

Three treatments were investigated.

1. Removal of the lesser vegetation, including the moss, to eliminate this source of competition. The vegetation was initially removed by hand-pulling. Thereafter this condition was maintained by monthly clipping during the growing season.
2. Trenching, to eliminate the root competition of the residual stand. The trenches were cut around areas 10 links by 20 links (2 milacre treatment units) and 10 links by 30 links (3 milacre treatment units) in size, for experiments 1 and 2 respectively. The trenches were left open and maintained each year.
3. Removal of the unincorporated organic material.

In experiment 1 the organic material was removed by raking. The material removed included any slash from previous logging, the litter and part of or all the F layer. The seedbed following this operation was a moist humus.

In experiment 2 the organic material was removed by raking and by burning. Raking was undertaken as in experiment 1. However, due to the nature of the organic material the seedbed following raking was practically a mineral seedbed.

Burning was accomplished by means of a torch, giving the effect of a very hot fire of short duration. The result was a seedbed approaching mineral soil.

The treatment and seeding of plots of both experiments were completed in September 1950. Two thousand spruce seeds were sown on each milacre quadrat. This seed, of local origin, was of the 1947 crop and proved to be approximately 20 per cent viable in sand flat tests undertaken during the summer of 1950. In addition, 330 lodgepole pine seeds were broadcast over each milacre plot of experiment 2. This seed was of the local 1950 crop and was found, by cutting tests, to be approximately 80 per cent filled.

Seedlings were counted and marked in the autumn of 1951 and each autumn thereafter until and including the autumn of 1955. Unfortunately one block of experiment 1 was accidentally destroyed in 1951, leaving seven blocks for analysis purposes.

Design of the Experiments

In both experiments, treatments were randomly applied in a split plot technique to eight replicate blocks, each of which was split into the appropriate number of milacre plots. These milacre plots were the ultimate treatment units. This technique is illustrated in Figure 1.

The blocks and plots were systematically lettered and labelled and treatments applied randomly as shown in Table 1.

TABLE 1. TREATMENT BY PLOTS WITHIN BLOCKS

EXPERIMENT 1

Milacre Plot	Replicate Blocks							
	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8
A	V.T.D.	T.D.	D.	T.	T.	T.D.	V.	T.
B	V.T.	T.	Control	T.D.	T.D.	T.	V.D.	T.D.
C	V.	D.	T.D.	D.	D.	Control	V.T.D.	D.
D	V.D.	Control	T.	Control	Control	D.	V.T.	Control
E	Control	V.	V.T.D.	V.T.D.	V.D.	V.T.D.	T.D.	V.T.D.
F	D.	V.D.	V.T.	V.T.	V.	V.T.	T.	V.T.
G	D.T.	V.T.	V.D.	V.D.	V.T.	V.	D.	V.
H	T.	V.T.D.	V.	V.	V.T.D.	V.D.	Control	V.D.

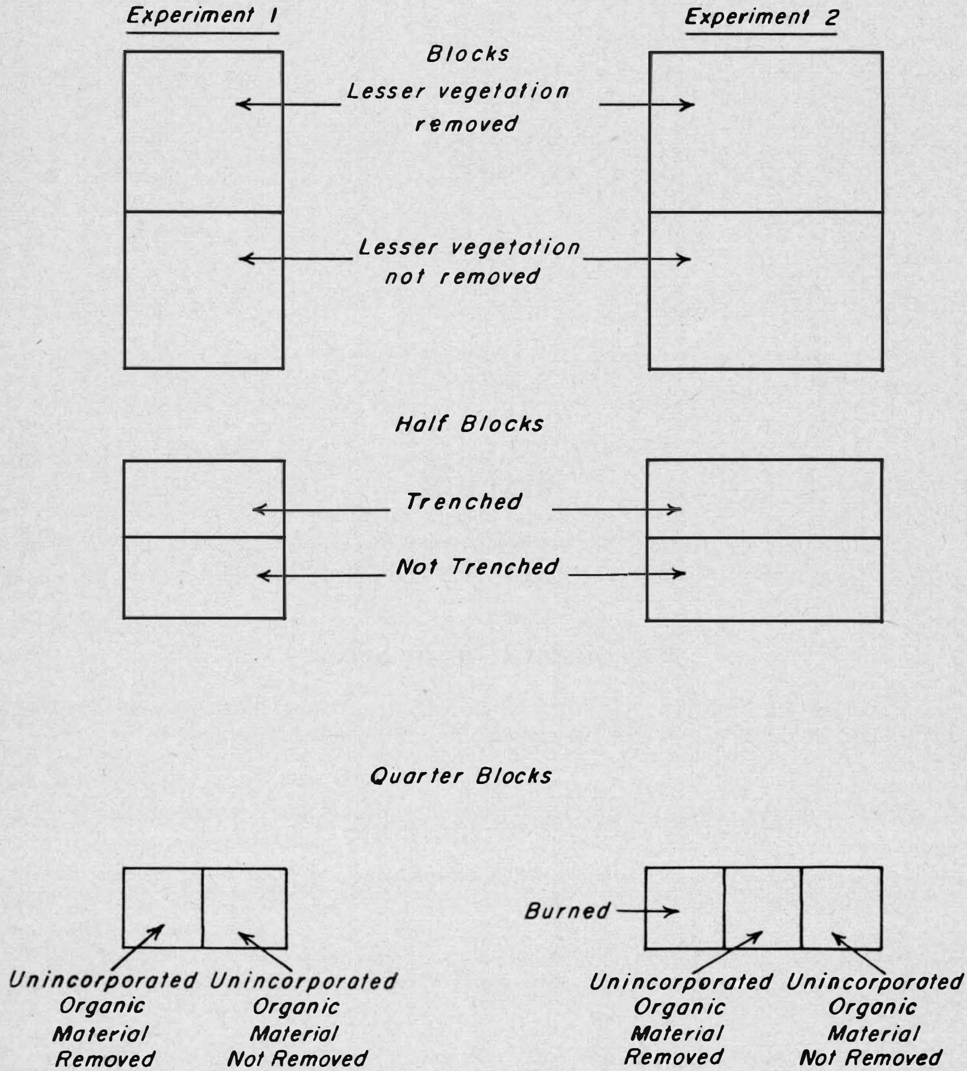
EXPERIMENT 2

Milacre Plot	Replicate Blocks							
	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8
A	V.B.	V.B.	V.T.D.	V.	V.B.	Control	V.D.	V.D.
B	V.D.	V.D.	V.T.	V.B.	V.D.	D.	V.	V.B.
C	V.	V.	V.T.B.	V.D.	V.	B.	V.B.	V.
D	V.T.D.	V.T.	V.D.	V.T.	V.T.D.	T.B.	V.T.	V.T.B.
E	V.T.	V.T.D.	V.	V.T.D.	V.T.B.	T.	V.T.B.	V.T.D.
F	V.T.B.	V.T.B.	V.B.	V.T.B.	V.T.	T.D.	V.T.D.	V.T.
G	D.	T.B.	Control	T.	T.	V.	T.	D.
H	Control	T.	B.	T.D.	T.B.	V.D.	T.D.	Control
I	B.	T.D.	D.	T.B.	T.D.	V.B.	T.B.	B.
J	T.D.	Control	T.D.	Control	Control	V.T.	B.	T.D.
K	T.	B.	T.B.	B.	D.	V.T.D.	D.	T.B.
L	T.B.	D.	T.	D.	B.	V.T.B.	Control	T.

V = vegetation removed
T = trenched
D = unincorporated organic material removed mechanically
B = unincorporated organic material removed by burning

Figure 1

Replicate Blocks Illustrating the Split Plot Technique Employed



Statistical differences were determined by a three-level analysis of variance, as follows:

Source	D.F.	
Main Plots	Experiment 1	Experiment 2
Replicates	6	7
V	1	1
Error A	6	7
Split Plots		
T	1	1
V x T	1	1
Error B	12	14
Split-split Plots		
D	1	2
V x D	1	2
T x D	1	2
V x T x D	1	2
Error C	24	56
Total	55	95

RESULTS

For reference purposes the statistical analyses of the number of seedlings alive in the autumn of 1955 have been placed in the Appendix.

Experiment 1: White Spruce

The best germination and survival occurred on those plots having both the vegetation and duff removed (Figures 2A and 2B, and Table 2).

TABLE 2. TOTAL NUMBER OF 1951 SEEDLINGS ALIVE AND CORRESPONDING PER CENT SURVIVAL BY TREATMENT AND YEAR

(Experiment 1: white spruce)

Treatment	1951		1952		1953		1954		1955	
	No.	% Survival	No.	% Survival	No.	% Survival	No.	% Survival	No.	% Survival
T	110	100	24	22	20	18	13	12	11	10
D	70	100	20	29	15	21	15	21	13	19
V	91	100	35	38	28	31	25	27	23	25
T.D	62	100	22	35	20	32	16	26	14	23
T.V	129	100	44	34	35	27	30	23	30	23
D.V	**243**	100	85	35	75	31	67	28	**67**	28
T.D.V	**184**	100	81	44	68	37	54	29	**53**	29
Control	84	100	16	19	15	18	15	18	14	17

Experiment I : Spruce

Fig. 2 A

Total No. of Seedlings Alive by Treatment & Year

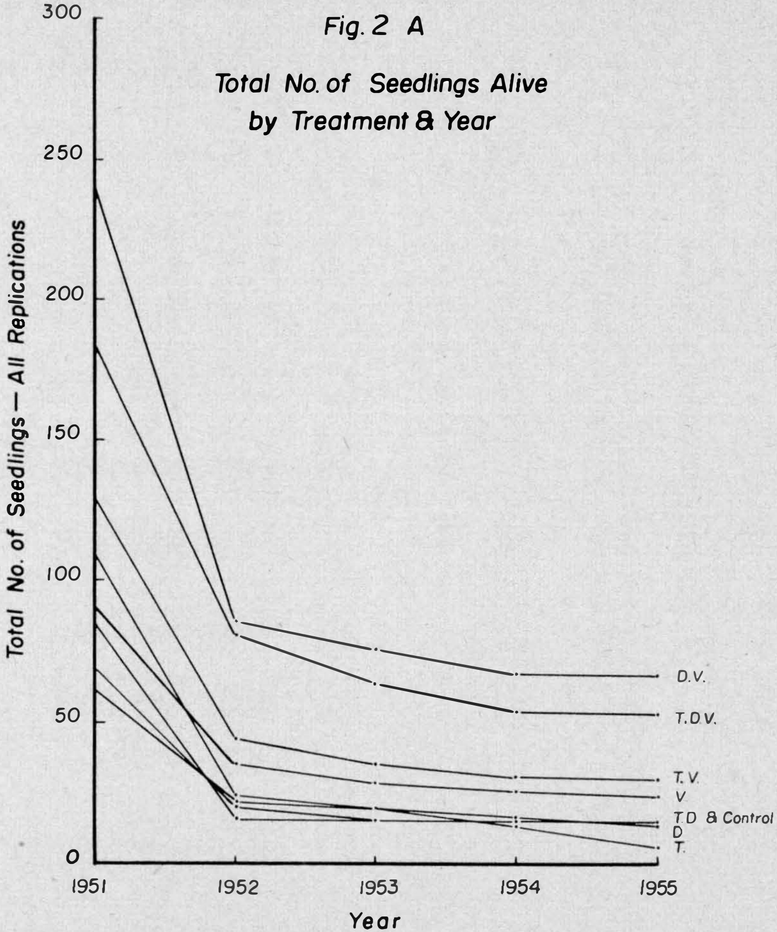
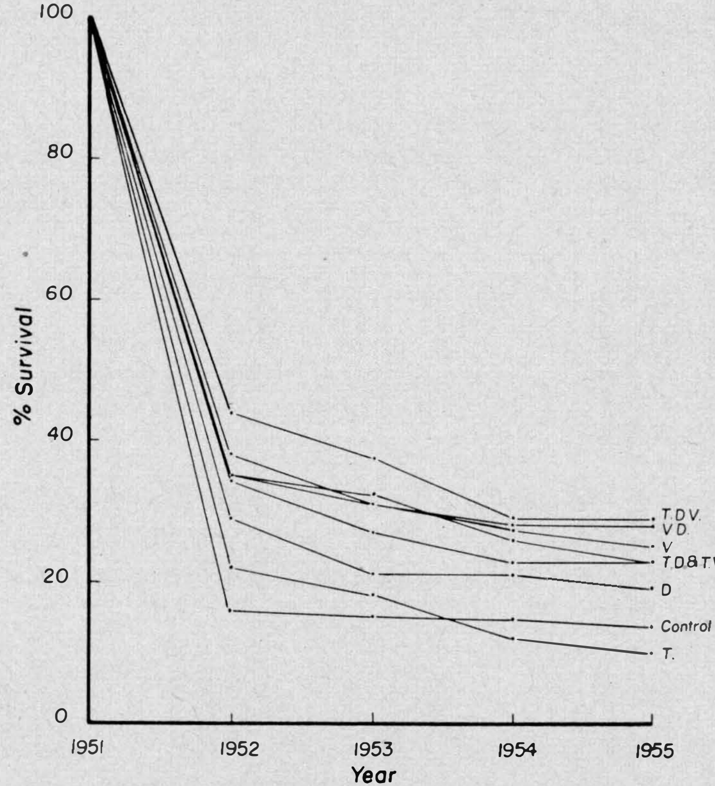


Fig. 2 B

Percent Survival 1951 — 1955 by Treatment & Year



Investigation of the 1955 differences by analysis of variance reveals that both main treatments, vegetation removal and duff removal, have improved germination and survival to a significant degree. It is evident however, from the 1955 subtotals presented below, that removal of organic material had a significant effect only if the vegetation was also removed.

Treatment	No. of Seedlings in 1955		Totals
	Duff Removed	Duff Not Removed	
Vegetation removed	120	53	173
Vegetation not removed	27	25	52
Totals	147	78	225

Trenching apparently had no influence on germination and survival. This is illustrated by the subtotals presented below and is verified by the statistical analysis.

Treatment	No. of Seedlings		Per Cent Survival
	1951	1955	
Trenched	485	108	22
Not trenched	488	117	24

Experiment 2: White Spruce

Reference to Figures 3A and 3B, and Table 3, again indicates that the best germination occurred following vegetation and duff removal.

TABLE 3. TOTAL NUMBER OF 1951 SEEDLINGS ALIVE AND CORRESPONDING PER CENT SURVIVAL BY TREATMENT AND YEAR

(Experiment 2: white spruce)

Treatment	1951		1952		1953		1954		1955	
	No.	% Survival	No.	% Survival	No.	% Survival	No.	% Survival	No.	% Survival
D	192	100	139	72	131	68	120	62	107	56
B	268	100	134	50	113	42	87	32	83	31
V	338	100	208	62	165	49	145	43	132	39
T	266	100	162	61	154	58	132	50	125	47
V.T	314	100	217	69	183	58	172	55	166	53
D.V	**450**	100	340	76	289	64	262	58	**245**	54
D.T	367	100	299	81	282	77	244	66	231	63
B.V	227	100	144	63	124	55	116	51	109	48
B.T	159	100	92	58	76	48	69	43	67	42
D.V.T	324	100	266	82	231	71	219	68	210	65
B.V.T	218	100	128	59	104	48	94	43	86	39
Control	255	100	183	72	160	63	140	55	119	47

Experiment 2 : Pine

Fig. 4 A

Total No. of Seedlings Alive
by Treatment & Year

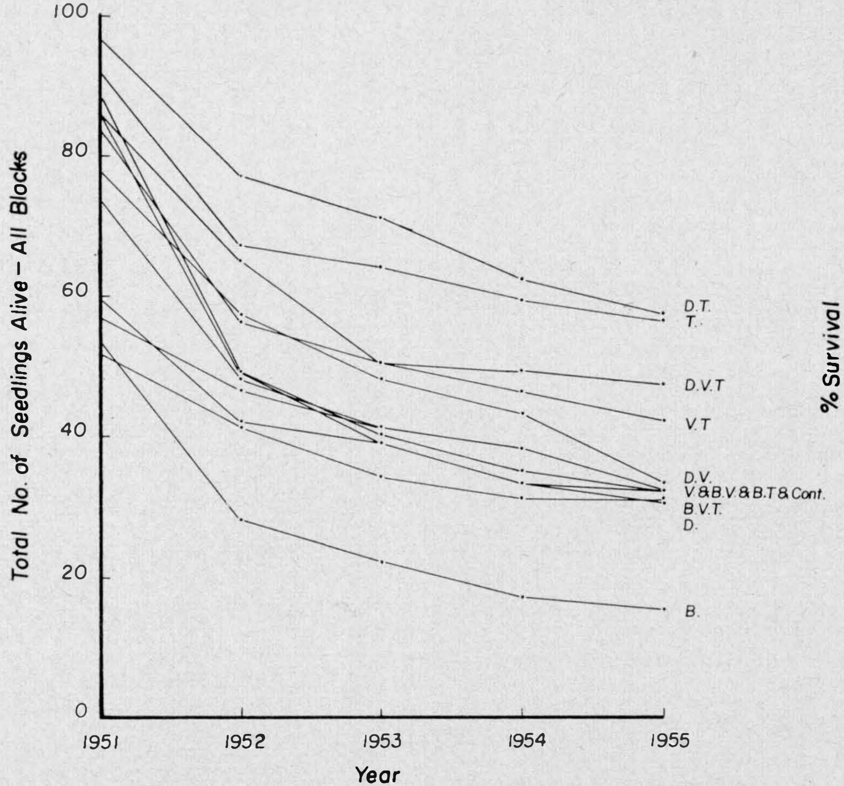
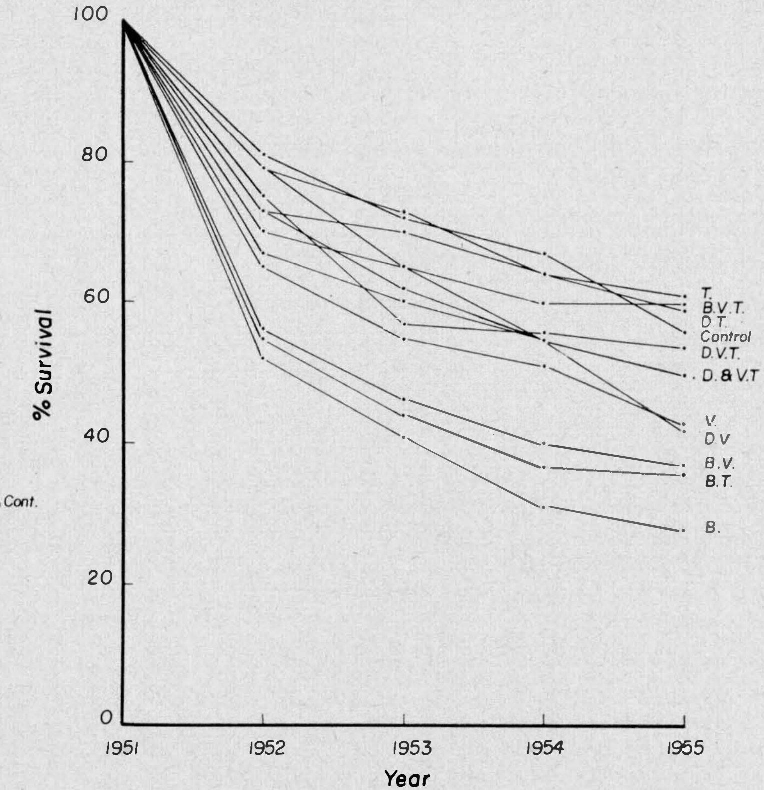


Fig. 4 B

Percent Survival 1951 — 1955
by Treatment & Year



The following table of subtotals summarizes the effect of vegetation removal.

Treatment	No. of Seedlings		Per Cent Survival
	1951	1955	
Vegetation removed	1,871	948	51
Vegetation not removed	1,507	732	49

Although suggestive of a beneficial effect, the differences between treatments was not significant at the 5-per-cent level.

Trenching again had no marked influence on germination and survival. This is illustrated by the subtotals presented below and is verified by the analysis of variance.

Treatment	No. of Seedlings		Per Cent Survival
	1951	1955	
Trenched	1,648	885	54
Not trenched	1,730	795	46

The only treatment on the dry lodgepole pine site which proved to be of significance, in both numbers of seedlings and per cent survival, was the method of duff removal. The number of seedlings and per cent survival as a result of this treatment are summarized below.

Treatment	No. of Seedlings		Per Cent Survival
	1951	1955	
Duff removed by mechanical means	1,333	793	60
Duff removed by burning	872	345	40
No duff removed	1,173	542	46

The variance in number of seedlings, for the most part, is attributed to differences between duff removal by mechanical means and duff removal by burning rather than to differences between either method and no duff removal. This complication was investigated by "t" test employing the 1955 means, and the only significant difference was found to be between duff removal by mechanical means and duff removal by burning.

Experiment 2: Lodgepole Pine

The results, by treatment and year, are presented in Table 4 and Figure 4A.

TABLE 4. TOTAL NUMBER OF 1951 SEEDLINGS ALIVE AND CORRESPONDING PER CENT SURVIVAL BY TREATMENT AND YEAR

(Experiment 2; lodgepole pine)

Treatment	1951		1952		1953		1954		1955	
	No.	% Survival	No.	% Survival	No.	% Survival	No.	% Survival	No.	% Survival
D	60	100	42	70	39	65	39	55	30	50
B	54	100	28	52	22	41	17	31	15	28
V	74	100	48	65	41	55	38	51	32	43
T	92	100	67	73	64	70	59	64	56	61
V.T	84	100	56	67	50	60	46	55	42	50
D.V	78	100	57	73	48	62	43	55	33	42
D.T	97	100	77	79	71	73	62	64	57	59
B.V	77	100	49	56	40	46	35	40	32	37
B.T	89	100	49	55	39	44	33	37	32	36
D.V.T	87	100	65	75	50	57	49	56	47	54
B.V.T	52	100	41	79	34	65	31	60	31	60
Control	57	100	46	81	41	72	38	67	32	56

Removal of the vegetation had no effect on the germination and survival of lodgepole pine seedlings. This is evident from the subtotals presented below.

Treatment	No. of Seedlings		Per Cent Survival
	1951	1955	
Vegetation removed	452	217	48
Vegetation not removed	449	222	49

Similarly, removal of the organic material had no appreciable influence on pine germination and survival.

Treatment	No. of Seedlings		Per Cent Survival
	1951	1955	
Duff removed by mechanical means	322	167	52
Duff removed during burning	272	110	40
No duff removal	307	162	53

In spite of the lack of significant differences, it is interesting to note that the treatment combinations which include duff removal by burning resulted in the lowest numbers of seedlings and per cent survival (Figures 4A and 4B).

Experiment 2 : Spruce

Fig. 3 A

Total No. of Seedlings Alive by Treatment & Year

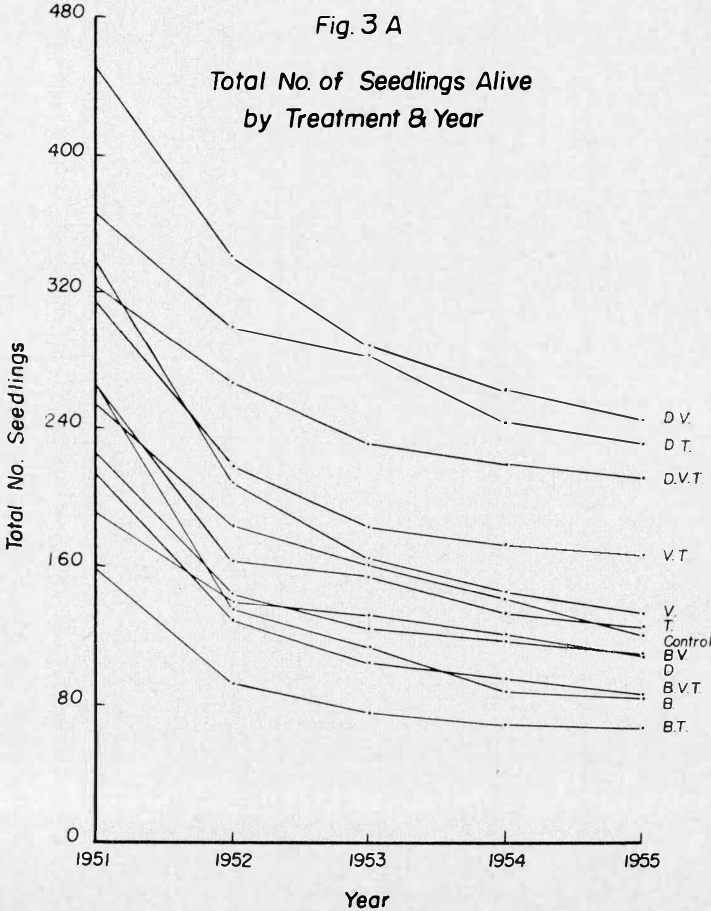
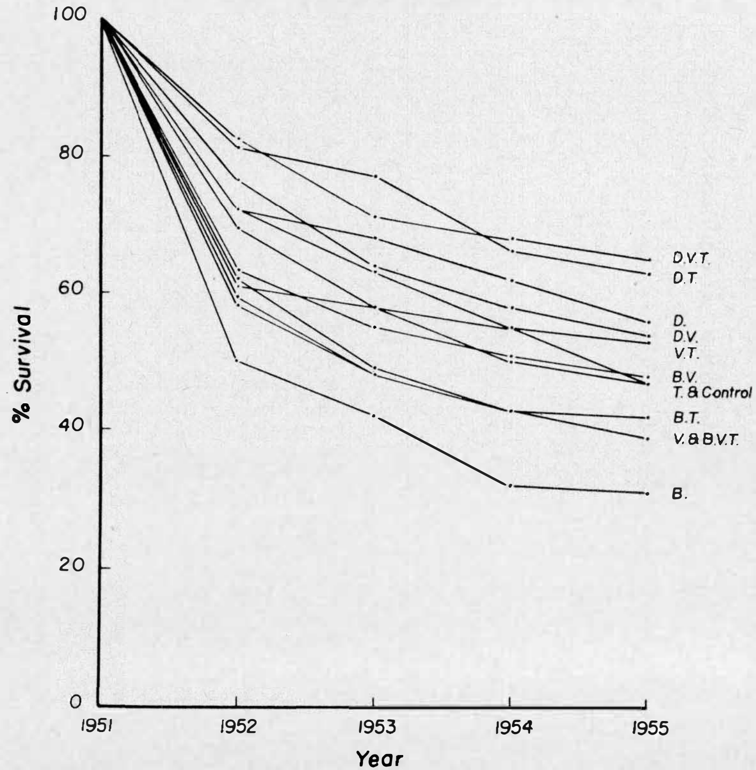


Fig. 3 B

Percent Survival 1951 — 1955 by Treatment & Year



Although trenching appeared to have no influence whatsoever on spruce germination and survival, Figures 4A and 4B indicate that lodgepole pine reacted favourably to this treatment. The relevant subtotals are as follows:

Treatment	No. of Seedlings		Per Cent Survival
	1951	1955	
Trenched	501	265	53
Not trenched	400	174	44

Statistical analysis of these data indicates that the differences in numbers of seedlings are not sufficiently large to be significant at the 5-per-cent level.

DISCUSSION

Before discussing these experiments it should be made clear that the results cannot indicate the degree of success to be obtained by applying the various treatments as regeneration methods. The results, however, do indicate which treatments offer hope of improvement.

The favourable influence of the removal of both the organic material and the minor vegetation in experiment 1 suggests that the primary obstacle to germination and survival on this site is the lack of a favourable initial rooting medium. Removal of that portion of the organic material which dries most rapidly improved the moisture-holding capacity of the rooting medium, and the removal of the minor vegetation reduced the competition for the available moisture. If all the organic material had been removed, thus bearing the mineral soil, the results might have been more pronounced.

The failure of trenching to improve the spruce results suggests that the root competition provided by the residual stand is not an important factor in the initial germination and survival of this species. This may reflect competition on different levels, the moisture conditions of the site or the tolerant nature of the species.

In experiment 2 the greatest numbers of spruce seedlings were found on those plots which had the vegetation and the duff removed. However, with the exception of a detrimental effect attributable to burning, the differences were not statistically significant. The difference in the spruce results between the two experiments may reflect the difference in the normal seedbed conditions of the two areas. Seedlings of experiment 1 had to contend with 5 to 12 inches of organic material while those of experiment 2 were not handicapped in this manner. In addition, the minor vegetation of area 1 is much more luxuriant than that of area 2. As suggested by Rowe (1955), severe competition from the minor vegetation, particularly on the better sites, is an important factor.

The difference in the reaction of spruce and pine seedlings to root competition of the residual stand might be explained by the difference in the inherent tolerance of the two species. It is well known that spruce seedlings are able to survive the shading and root competition of an overstory. Conversely, lodgepole pine seedlings are extremely sensitive in this respect and are seldom found under these conditions.

The relatively poor results for both spruce and pine on the burned seedbed of experiment 2 were not expected. This treatment, alone or in combination with others, invariably resulted in the poorest germination and survival. Since lodgepole pine is a recognized fire type, there is some justification for assuming that successful regeneration is partially dependent upon a burned seedbed. The marked success of this species on the drier Subalpine sites following fire may be due largely to the accompanying abundance of seed and removal of the overstory rather than to favourable modification of the seedbed. Rowe (1953) noted the delayed germination of spruce seed on burned seedbeds, and concluded that such delayed germination is important because unhardened late germinates are likely to succumb to winter conditions. This may explain the comparatively low survival between 1951 and 1952, but does not explain the low numbers of seedlings tallied in the autumn of 1951, before the first winter. It is possible that high summer temperatures on the blackened surface during the first season contributed to the low germination and initial survival. It is also possible that the fire was not severe enough to accomplish its purpose. Rowe (1955) states that light surface fires may not produce satisfactory conditions for spruce establishment because they stimulate the growth of competing plants.

The significant results attributable to vegetation and duff removal on the site of experiment 1 lends support to the practice of scarification as a regeneration method in Alberta. However, the lack of significant results attributable to these treatments on the site of experiment 2 suggests that scarification may not be of appreciable value on the drier sites of the Subalpine Region, where vegetation is not heavy and the depth of organic material is not great. An example of satisfactory regeneration following logging, under similar seedbed conditions, has been described by Crossley (1952). Other instances have been observed by the writer. This condition exists on much of the Subalpine Region presently supporting lodgepole pine, but has received little attention since these sites seldom support merchantable timber.

Experiment 2 was not conducted in a completely open area although all plots were located in openings in a thinned stand at least large enough to accomodate the individual plot (20 by 26 feet). Nevertheless, the results following trenching indicate that the residual stand was an important factor in the germination and survival of lodgepole pine on this site. The question follows whether light has been a limiting factor in the lodgepole pine results, and whether the reaction to the individual treatments might have been quite different had the experiment been conducted following complete removal of the overstory. Considering the intolerant nature of this species however, the surprisingly good germination and survival, illustrated in Figures 4A and 4B, argue against such a conclusion.

SUMMARY AND CONCLUSIONS

On the assumption that the amount of available moisture is an important factor in seedling survival, an experiment was undertaken in 1951 in the Subalpine Region of Alberta to determine the relative influence of the lesser vegetation, the unincorporated organic material, and the root competition of the residual stand on the germination and survival of western white spruce and lodgepole pine seedlings.

Two individual experiments were undertaken: experiment 1 with white spruce on a moist site that is typical of the better conditions being logged in the Subalpine Region; and experiment 2 with white spruce and lodgepole pine on a site representative of the more common, comparatively dry, lodgepole pine areas.

The results after five growing seasons, although in some cases non-significant statistically, generally confirm that removing one or more of the sources of competition for available moisture improves germination and survival. It is also apparent however, that the relative degree of effectiveness of the factors investigated will vary with the species and the condition of the site, i.e., the amount of available moisture, the type and abundance of vegetation, and the depth to mineral soil.

The conclusions pertaining to the individual treatments tested are summarized as follows:

Spruce

1. Trenching had no influence on germination and survival, indicating that the root competition of the residual stand is not an important factor in spruce seedling survival. This may be a reflection of the inherent tolerance of the species, competition at different levels, or adequate soil moisture for all demands.
2. In experiment 1 the removal of both the vegetation and the driest portion of the unincorporated organic material significantly improved germination and survival. A deep organic layer and luxuriant vegetation are absent on the site of experiment 2, and the differences as a result of their removal were not sufficiently large to be significant.
3. Removal of the organic material by burning, on the site of experiment 2, had an adverse effect on germination and survival.

Lodgepole Pine

1. Removal of the vegetation, the unincorporated organic material, or both, had no appreciable influence on pine germination and survival on the site of experiment 2.
2. Trenching had a beneficial effect on pine germination and survival, indicating that the root competition of the residual stand is an important factor in the germination and survival of this species.
3. As with the spruce, removal of the unincorporated organic material by means of fire had an adverse effect on germination and survival.

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APPENDIX

Experiment 1: White Spruce

Analysis of variance: No. of seedlings alive after five seasons (1955)

Source	D.F.	S.S.	M.S.	F.	Sig.
Main Plots					
Replicates	6	123	20.50	1.86	N.S.
V	1	261	261.00	23.73	S. (1%)
Error A	6	66	11.00		
Split-plots					
T	1	1	1.00	<1	N.S.
V. x T	1	1	1.00	<1	N.S.
Error B	12	80	6.67		
Split-split plots					
D	1	85	85.00	4.36	S. (5%)
V. x D	1	76	76.00	3.90	N.S.
T. x D	1	6	6.00	<1	N.S.
V. x T. x D	1	10	10.00	<1	N.S.
Error C	24	468	19.50		
Totals	55	1,177			

Experiment 2: White Spruce

Analysis of Variance: No. of seedlings alive after five seasons (1955)

Source	D.F.	S.S.	M.S.	F.	Sig.
Main Plots					
Replicates	7	4,120	588.57	2.48	N.S.
V	1	486	486.00	2.05	N.S.
Error A	7	1,660	237.14		
Split-plots					
T	1	84	84.00	<1	N.S.
V. x T	1	199	199.00	<1	N.S.
Error B	14	2,906	207.57		
Split-split plots					
D	2	3,151	1,575.50	5.66	S. (1%)
V. x D	2	96	48.00	<1	N.S.
T. x D	2	261	130.50	<1	N.S.
V. x T. x D	2	617	308.50	1.11	N.S.
Error C	56	15,588	278.36		
Totals	95	29,168			

T. Test-D. (1955)

Means
D. = ... 24.78
B. = ... 10.78
N.D. = ... 16.94

D. −ND. = 7.84 N.S.
D. −B. = **14.00 S (1%)**
B. −ND = 6.16 N.S.

Standard error = $\sqrt{2Ec/32}$ = ± 4.17 (56 D.F.)
Critical diff. @ 5% = 4.17 x 2.00 = **8.34**
" " 1% = 4.17 x 2.67 = **11.13**

Experiment 2: Lodgepole Pine

Analysis of Variance: No. of seedlings alive after five seasons (1955)

Source	D.F.	S.S.	M.S.	S.	Sig.
Main Plots					
Replicates	7	239	34.14	1.40	N.S.
V.	1	0	0	0	N.S.
Error A	7	171	24.43		
Split-plots					
T.	1	86	86.00	3.66	N.S.
V. x T.	1	21	21.00	<1	
Error B	14	329	23.50		
Split-split plots					
D.	2	62	31.00	1.18	N.S.
V. x D.	2	15	7.50	<1	N.S.
T. x D.	2	10	5.00	<1	N.S.
V. x T. x D.	2	2	1.00	<1	N.S.
Error C	56	1,470	26.25		
Totals	95	2,405			

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