Effect of SEEDBED PREPARATION on Natural Reproduction of Spruce and Hemlock under Dense Shade

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Need for Reproduction

THE cutting practices commonly recommended for spruce-fir stands in the Northeast involve uneven-aged management. The success of this type of management is predicated upon stand structures that have a range of size classes from seedlings to mature trees in intimate mixture. This kind of stand structure requires a continuous supply of reproduction of desirable species. And this reproduction must be established under an overstory.

Some advance reproduction is usually present in spruce-fir stands. But often it is slow in becoming established, is unevenly distributed, and is not always of the desired species. Under intensive management the forester needs a technique for establishing reproduction when and where it is wanted. It should not be left to chance.

The principal reason offered by investigators (*7*, *6*, *11*, *5*, *8*) for failure of spruce and fir to regenerate satisfactorily is the thick humus layer found under softwood stands. Humus does not retain moisture; consequently, roots of seedlings dry out before they reach the moisture supply in mineral soil.

To test the effects of several treatments of the humus and upper soil layers upon germination and survival of softwood seedlings under dense softwood stands, a study was made in 1953-57 on the Penobscot Experimental Forest near Bangor, Maine. This is a report on the results of that study.

The Study Area

The study area lies at an elevation of about 100 feet above sea level. Soils are acid stony loams developed from mixed glacial till, neither poorly nor excessively drained. The humus (L, H, and F layers collectively) varied from slightly less than 1 inch to about 5 inches thick, ranging mostly from 1 to 2 inches. There was no understory cover. Eight stands were sampled: six were predominantly hemlock with a high proportion of red spruce, one was predominantly white spruce, and one was balsam fir. The basal area ranged from 112 to 196 square feet per acre (table 1).

Table 1. — *Basal area per acre in trees 0.6 inch d.b.h. and larger, in square feet*

Species	Location							
	1	2	3	4	5	6	7	8
Hemlock	96.57	102.49	7.01	112.65	20.43	104.54	121.11	59.90
Spruce	17.30	65.80	73.81	63.64	3.02	73.08	.49	43.30
Fir	.13	--	7.39	5.08	99.21	2.17	18.99	29.28
Other softwoods[1]	15.24	1.09	3.02	--	4.13	--	22.03	11.96
All softwoods	129.24	169.38	91.23	181.37	126.79	179.79	162.62	144.44
Hardwoods[2]	3.02	7.64	20.34	15.13	12.36	7.52	5.92	13.18
All species	132.26	177.02	111.57	196.50	139.15	187.31	168.54	157.62

[1]Northern white-cedar and eastern white pine.

[2]Red maple and paper birch.

Procedures

The study involved eight seedbed treatment combinations. Also, the amount of seed falling at each location was determined. And some data were taken on other factors that may influence regeneration, including the population of mice and voles, weather conditions, and accumulations of hardwood leaf litter.

Seedbed Preparation

Eight milacre plots arranged in two groups of four were established at each of the eight locations. In one group at each location, the individual plot boundaries were trenched with a mattock to a depth of 6 inches; plots in the other group were not trenched. The purpose of the trenching was to eliminate all or at least most of the root competition. Surface treatments as listed below were assigned at random in each four-plot group:

1. Control—no disturbance of the humus.
2. Humus removed by mattock to expose mineral soil.
3. Humus and mineral soil mixed by mattock to a depth of at least 2 inches.
4. Litter and humus burned in place.

The treatments were applied in August 1953. The burning was only partly successful: in general only the litter and the upper part of the H-layer were consumed.

Seedfall Count

One 3-foot-square seed trap was placed at each of the eight locations in August 1953. Trapped seeds were collected at approximately monthly intervals until it became impracticable because of snow in December. The next and final collection was made in the middle of May, 1954.

Seeds were separated from debris, identified, and counted for each collection from each trap or area. Samples of the seeds were cut or mashed to estimate the percentage of viable seed.

Results

Germination

Seedling counts were made in August and November 1954, October 1955, September 1956, and September 1957. Although there was an appreciable seedfall in 1953 of balsam fir, northern white-cedar, and paper birch (table 5), plus an unrecorded fall of red maple seed during the summer of 1954, only a scattered few seedlings of these species were found on the plots in the fall of 1954. Only hemlock and spruce seedlings appeared in such quantity that their numbers could be related to the study variables. Therefore results are presented only for hemlock and spruce. Hemlock seedlings were so numerous that they were counted on only 10 or 20 percent of each milacre, depending on seedling density. Spruce seedlings were counted on 40 percent of each milacre.

The numbers of seedlings of both species found in the fall of 1954 varied greatly between locations. Trenching had no effect on germination of either species, regardless of seedbed treatment. However, there was a definite relationship between method of seedbed treatment and the number of both spruce and hemlock seedlings.

With hemlock, the best seedling catch in 1954 was on plots where humus had been removed, and the poorest was on burned plots (table 2). For statistical analysis of the 1954 results, numbers of seedlings recorded for each humus treatment (trenched and untrenched combined) were converted to percentages of the total for all treatments, the arcsine transformation was applied; and the transformed data were subjected to analysis of variance. Differences between the control and each of the other treatments were all statistically significant.

With spruce, the best seedling catch in 1954 also was on plots where humus had been removed; but the poorest was on the control plots (table 3). However, numbers of seedlings ran much lower for spruce than for hemlock in all treatments. An analysis similar to that made for hemlock showed significant differences between the control plot and those where humus was removed and humus was mixed, but not between control plot and burned plot.

Table 2. — *Number of hemlock seedlings per acre in 1954 and survival through 1957, by treatments*

Humus treatment	1954	1955		1956		1957	
	Number	Number	Survival rate	Number	Survival rate	Number	Survival rate
	Thousands	Thousands	Percent	Thousands	Percent	Thousands	Percent
				TRENCHED			
Removed	3,802	731	19.2	547	14.4	170	4.5
Mixed	2,849	461	16.2	353	12.4	80	2.8
Burned	941	194	20.6	149	15.8	57	6.1
Control	1,789	401	22.4	316	17.7	127	7.1
Average	2,345	447	19.1	341	14.5	108	4.6
				UNTRENCHED			
Removed	4,683	393	8.4	298	6.4	48	1.0
Mixed	1,976	229	11.6	199	10.1	25	1.3
Burned	763	35	4.6	27	3.5	11	1.4
Control	1,205	33	2.7	23	1.9	4	.3
Average	2,157	172	8.0	137	6.4	22	1.0
				ALL AREAS			
Removed	4,242	562	13.2	422	9.9	109	2.6
Mixed	2,412	345	14.3	276	11.4	52	2.2
Burned	852	114	13.4	88	10.3	34	4.0
Control	1,497	217	14.5	170	11.4	66	4.4
Average	2,251	310	13.8	239	10.6	65	2.9

Table 3. — *Number of spruce seedlings per acre in 1954 and survival through 1957, by treatments*

Humus treatment	1954	1955		1956		1957	
	Number	Number	Survival rate	Number	Survival rate	Number	Survival rate
	Thousands	Thousands	Percent	Thousands	Percent	Thousands	Percent
				TRENCHED			
Removed	71	19	26.8	16	22.5	12	16.9
Mixed	45	17	37.8	9	20.0	6	13.3
Burned	36	11	30.6	6	16.7	3	8.3
Control	20	4	20.0	2	10.0	1	5.0
Average	43.00	12.75	29.6	8.25	19.2	5.50	12.8
				UNTRENCHED			
Removed	81	4	4.9	3	3.7	2	2.4
Mixed	46	7	15.2	6	13.0	1	2.2
Burned	24	1	4.2	1	4.2	0.25	1.0
Control	6	1	16.7	0.5	8.3	0	0
Average	39.25	3.25	8.3	2.62	6.7	0.81	2.1
				ALL AREAS			
Removed	76	11.5	15.1	9.5	12.5	7.0	9.2
Mixed	46	12.0	26.1	7.5	16.3	3.5	7.6
Burned	30	6.0	20.0	3.5	11.7	1.62	5.4
Control	13	2.5	19.2	1.25	9.6	0.5	3.8
Average	41.25	8.0	19.4	5.44	13.2	3.16	7.7

The contrasting responses of the two species to burned seedbeds (hemlock poorer, but spruce better on burned plots than on controls) was quite consistent. We cannot explain this. Burned seedbeds appeared to be drier at the surface than the others, but there is no obvious reason why this should affect one species differently than the other.

Both 1954 and 1955 were poor seed years, but both hemlock and spruce bore heavy cone crops again in 1956. Seedling counts in the fall of 1957—the fourth year after the plots were installed —showed that the treated seedbeds still were receptive to seed of both species (table 4). The same general relationships were evident as in the 1954 counts, but to a lesser degree. Among the new seedlings, only the catch on the humus-removed plots differed significantly from that on the controls; this was true for both species.

Table 4. — *Number of seedlings per acre from 1956 crop — counted in 1957*

(In thousands of seedlings)

Humus treatment	Trenched		Untrenched		All areas	
	Hemlock	Spruce	Hemlock	Spruce	Hemlock	Spruce
Removed	1,586	94	1,820	146	1,703	120
Mixed	1,794	66	1,587	60	1,690	63
Burned	785	67	711	68	748	68
Control	1,173	50	964	54	1,068	52
Average	1,334	69	1,270	82	1,302	76

Survival

Numbers of seedlings from the 1953 seed crop dropped sharply from 1954 to 1955, less between succeeding years (figures 1 and 2; tables 2 and 3). For all treatments combined, 14 percent of the hemlock and 19 percent of the spruce seedlings survived the first year. Hemlock seedlings dropped from more than 2.25 millions per acre to 310,000 per acre the first year; spruce seedlings from about 41,000 to 8,000 per acre during the same period. By the end of the fourth year 3 percent of the hemlock and

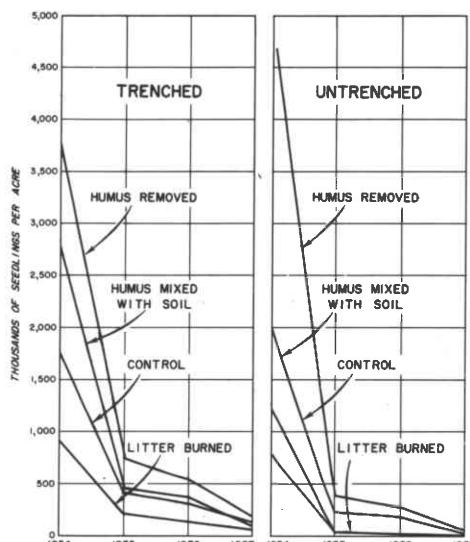

Figure 1.—Number of hemlock seedlings per acre, by year.

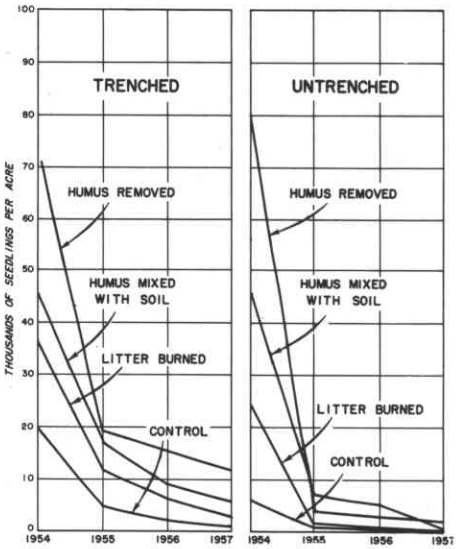

Figure 2.—Number of spruce seedlings per acre, by year.

nearly 8 percent of the spruce, or 65,000 hemlock and 3,160 spruce seedlings per acre, still were alive.

Of the individual plot treatments, only trenching improved survival. At the end of the fourth year 4.6 percent of the hemlock seedlings on trenched plots survived, compared to 1.0 percent on untrenched plots (table 2). Respective survivals for spruce were 12.8 percent and 2.1 percent (table 3). The differences in survival between trenched and untrenched plots were significant for both species by chi-square tests.

Factors Influencing Germination and Survival

Seed Production in 1953

Data from the seed traps showed that hemlock and paper birch produced excellent seed crops in 1953; red and white spruces produced fairly good crops; balsam fir and northern white-cedar had poor crops (table 5). Estimates of percentages of the seed that were sound also are shown in table 5. When these percentages are applied to the total figures, we estimate some 13½ million sound hemlock seeds per acre, as compared to 335,000 sound spruce seeds and 10,000 sound balsam fir seeds. So it is not surprising that hemlock seedlings on our plots greatly outnumbered those of other species.

Table 5. — *Number of seeds per acre and percent of sound seed, 1953*

(In thousands of seeds)

Location	Hemlock	Spruce[1]	Balsam fir	Cedar	Birch[2]
1	27,414	397	10	19	1,452
2	39,582	1,171	34	0	286
3	4,855	1,452	5	155	4,390
4	16,964	1,529	15	29	169
5	11,519	649	440	10	421
6	13,504	842	5	0	460
7	38,797	363	77	494	2,251
8	23,251	145	131	82	8,538
All	21,986	818	90	99	2,246
Percent sound	62	41	11	12	62

[1]Red and white spruce seeds were not separated. Both species produced heavy cone crops.

[2]Practically all paper birch. Less than 1 percent was gray birch. No yellow birch. Birch made up less than 5 percent of the stand basal area.

The ratio of seeds to seedlings varied widely among locations and species. To produce one seedling a year after seedfall required 5 to 15 seeds for hemlock, 5 to 70 for spruce. At 4 years after seedfall, numbers of seeds per live seedling jump to 50 to 10,000 for hemlock, 80 to 3,400 for spruce.

Hardwood Leaf Cover

Several reports (*1*, *4*, *3*, *10*) indicate that hardwood leaf litter may be an important cause of mortality of young softwood seedlings. Consequently, the percentage of plot area covered by hardwood leaves was recorded at the time of each autumn count of seedlings (except August 1954).

The results were in accord with reports that hardwood leaf litter adversely affects seedling survival. Where less than 25 percent of the plot area was covered by leaves, average hemlock mortality was 30 percent during the period August to November

1954; on plots that were more than 25 percent covered mortality averaged 54 percent. Spruce mortality was 38 percent and 62 percent respectively on plots with less and more than 25 percent cover. However, there was no consistent increase in mortality of either species with increasing coverage above 25 percent.

Hardwood leaf litter was most detrimental during the first year after germination. During the second year, from November 1954 to October 1955, hemlock mortality was 79 percent, regardless of leaf cover; spruce mortality was 62 percent on plots where the leaf cover was less than 25 percent and 76 percent where it was greater.

Other Factors

The growing season of 1954 was one of the wettest on record, being 67 percent above the long-term average. Temperatures were normal. Precipitation during the growing seasons of 1955, 1956, and 1957 was below the long-term average, but was well distributed from May to September; so the seedlings were not subjected to any extended periods of drought.

Since there were large differences among locations in germination and survival of both hemlock and spruce (table 6), an attempt was made to discover the factors responsible. For hemlock, seedling catches were roughly correlated with local seed crops: locations 1, 2, 7, and 8 had the heaviest seedfalls (table 5) and the highest seedling catches, although not in the same order.

Table 6. — *Per-acre seedling catches in 1954 and survivals in 1957, by locations*

Location	Hemlock			Spruce		
	1954	1957	Survival	1954	1957	Survival
	1,000 seedlings	1,000 seedlings	Percent	1,000 seedlings	1,000 seedlings	Percent
1	2,392	13	0.54	64.00	1.12	1.76
2	5,661	29	.51	19.50	1.00	5.13
3	1,191	89	7.47	14.50	2.75	18.97
4	1,606	111	6.91	126.00	18.75	14.88
5	691	36	5.21	9.40	.25	2.66
6	828	2	.30	77.00	.25	.32
7	2,636	4	.15	12.00	.75	6.25
8	3,004	203	6.76	5.60	1.25	22.32

For spruce, little correlation could be discerned: locations 2, 3, and 4 had the heaviest seedfalls, but of these only location 4 showed a high catch of seedlings. On the other hand, locations 1 and 6, which did not rank high in seedfall, did rank high in catch of seedlings.

Since spruce seed, in particular, is known from other studies to be a favorite food for small rodents, one might suspect that the poor correlation between seedfall and seedling catch of this species resulted from unequal populations of mice and voles at the different locations. In anticipation of questions about small-animal relationships, a mouse and vole census was made by snap-trapping at each location in the fall of 1953. The census showed populations (predominantly red-backed voles) ranging from 7 to 16 animals per acre; and according to studies at the University of Maine (9), 1953 was a peak year in the population cycle for that area. However, there were no obvious relationships between these mouse and vole populations at the different locations and the catches of spruce seedlings.

When we examine survivals, locations 3, 4, and 8—which ranked highest for both hemlock and spruce (table 6)—are of particular interest. In looking for reasons why survivals were higher at these locations, we suspected differences in soil or stand density. However, soil types at locations where survival was high were represented also at locations where survival was low. And although location 3 had the lowest basal area among all locations in the study, location 4 had the highest basal area (table 1). So, neither of these factors alone seems to have been the controlling one in seedling survival.

There may be a relationship between stand composition and seedling survival: high-survival locations 3, 4, and 8 also were among the highest in percentage of basal area in hardwoods (table 1). Possibly more light filtered through these mixed canopies than through those that were more nearly pure conifer. However, inasmuch as hardwood leaf litter was found to be detrimental to survival, the apparent association of higher survivals with higher proportions of hardwoods in the overstory creates a seeming paradox. Actually, so long as the hardwood component is definitely in the minority and hardwood litter accumulations are small and patchy, both relationships could well be true: seedling survival would be less in the patches of litter, but the overall effect of a mixed canopy still could be more favorable than pure conifer.

Without more data than this study provided on such basic environmental factors as light, soil moisture, and temperature, it seems fruitless to speculate further on reasons for the considerable variation among locations in both germination and seedling survival.

Summary and Recommendations

In 1953 a study was undertaken on the Penobscot Experimental Forest near Bangor, Maine, to investigate the effect of several seedbed treatments on spruce and hemlock reproduction under dense softwood stands. Analysis of data collected for four growing seasons showed that:

1. Spruce and hemlock seeds can germinate under dense softwood stands, and some seedlings can survive at least 4 years.

2. Removal of the humus layer to expose mineral soil, or mixing the humus with mineral soil, resulted in much more favorable seedbeds than either burning or leaving the humus undisturbed. Treated seedbeds remained receptive for at least 3 years.

3. Trenching to remove root competition did not increase germination, but it did increase survival.

4. Where hardwood leaf litter covered more than 25 percent of the area, seedling survival during the first year after germination was substantially less than where leaf cover was sparse.

5. There was much variation in germination and survival among locations, for which the causes are unknown.

Practical recommendations supported by the study results are:

- When practicing selection management, make cuttings when the soil is not frozen or covered with snow. This will break up the humus and mix it with mineral soil, and will reduce root competition to some degree.

- Log during good seed years whenever practicable. However, scarified seedbeds remain receptive long enough to allow some leeway in timing logging operations.
- Remove hardwoods insofar as practicable to minimize accumulations of hardwood litter on newly germinated softwood seedlings.

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Literature Cited

(1) Crossley, D. I.
1952. WHITE SPRUCE REPRODUCTION RESULTING FROM VARIOUS METHODS OF FOREST SOIL SCARIFICATION. Canada Dept. Resources and Devlpmnt, Forestry Branch. Silv. Res. Note 102, 18 pp., illus.

(2) Grisez, Ted J.
1954. RESULTS OF A MOUSE CENSUS IN A SPRUCE-FIR HEMLOCK FOREST IN MAINE. U. S. Forest Serv. Northeast. Forest Expt. Sta. Forest Res. Note 28, 2 pp.

(3) Holt, Leif.
1955. WHITE SPRUCE SEEDBEDS AS RELATED TO NATURAL REGENERATION. Pulp and Paper Res. Inst. Canada, Woodlands Sec., 28 pp.

(4) Koroleff, A.
1954. LEAF LITTER IS A KILLER. Jour. Forestry 52: 178-182.

(5) Long, H. D.
1946. OBSERVATIONS ON SPRUCE REGENERATION. Pulp and Paper Mag. Canada 47 (3): 67-68.

(6) Moore, Barrington.
1926. INFLUENCE OF CERTAIN SOIL AND LIGHT CONDITIONS IN THE ESTABLISHMENT OF REPRODUCTION IN NORTHEASTERN CONIFERS. Ecology 7: 191-220.

(7) Murphy, Louis S.
1917. THE RED SPRUCE — ITS GROWTH AND MANAGEMENT. U. S. Dept. Agr. Bul. 544, 100 pp., illus.

(8) Place, I. C. M.
1955. THE INFLUENCE OF SEEDBED CONDITIONS ON THE REGENERATION OF SPRUCE AND BALSAM FIR. Canada Dept. North. Affairs and Nat. Resources Forestry Branch Bul. 117, 87 pp., illus.

(9) Quick, Horace F.
1955. RODENT POPULATIONS ON THE UNIVERSITY FOREST. Univ. Maine Forestry Dept. Tech. Note 41, 3 pp.

(10) Rowe, J. S.
1955. FACTORS INFLUENCING WHITE SPRUCE REPRODUCTION IN MANITOBA AND SASKATCHEWAN. Canada Dept. North. Affairs and Nat. Resources Forestry Branch Tech. Note 3, 27 pp., illus.

(11) Westveld, M.
1931. REPRODUCTION ON PULPWOOD LANDS OF THE NORTHEAST. U. S. Dept. Agr. Tech. Bul. 223, 52 pp., illus.