Seedling Survival in Spruce-Fir After Mechanical Tree Harvesting in Strips

by Robert M. Frank
and Eugene L. Putnam

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FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
WARREN T. DOOLITTLE, DIRECTOR

THE AUTHORS

ROBERT M. FRANK, research forester, received a bachelor of science degree in forestry from The Pennsylvania State University in 1954 and a master of forestry degree in forest products from the same university in 1956. He joined the USDA Forest Service in 1957 and has served in economics research, forest survey, and mine-spoil revegetation projects of the Northeastern Forest Experiment Station. At present he is on the staff of the Station's spruce-fir silviculture project at Orono, Maine.

EUGENE L. PUTNAM, industry forester, received his associate degree in liberal arts from Ricker College in 1954, and his bachelor's degree in forestry from the University of Maine in 1957. He joined the Great Northern Paper Company in February 1957, and has worked out of its Woodlands Office in Bangor, Maine, ever since, except, for two years in the Army. He is now assistant superintendent of the Division of Forest Engineering, Timberland Management.

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SMALL SEEDLINGS SURVIVE

MECHANICAL TREE HARVESTING is a fairly new venture in the northeastern spruce-fir forests. These machines, either track or wheel mounted, are capable of performing one or several processing functions with a minimum of help from men on the ground. The Beloit machine, used for this study, crawls into a stand, grasps a tree and quickly trims off the branches, clips off the top, shears it off at the base, and then lays the branchless and topless tree in a pile for rubber-tired skidders to haul away.

Use of these machines has prompted several questions about the natural ability of the cleared strips to produce a new crop of trees of the desired species. It is known that reproduction is usually present in spruce-fir stands. The specific questions are: How much damage is done to the stocking of seedlings in the understory during the harvesting operation? And what happens to the surviving seedlings in their drastically changed environment?

Some answers to these questions were obtained in a recent study in Maine. We concluded that, after winter logging with a mechanical harvester, the stocking of surviving seedlings in most of the logged areas remains adequate for at least 2 years after logging.

THE STUDY

The study was begun in 1966 in a spruce-fir forest 35 miles west of Caribou, Maine (46° 50″ N. latitude, 68° 42″ W. longitude), at an elevation of approximately 700 feet. The topography is mostly flat to gently sloping, with maximum grades of about 20 percent. The study was restricted to stands containing at least 50 percent spruce and fir by volume.

This was a cooperative study, done on land owned in common, undivided, and managed by the following: Pingree, Wheatland, and Phillips Interests, managed by Seven Islands Land Co.; Great Northern Paper Co.; Griswold Heirs, managed by Prentiss and Carlisle Co., Inc.; and J. M. Huber Corp.

Here in northern Maine, winter is long, and snow is likely to form a cover from November through April. The frost-free season is approximately 100 days. The mean annual temperature is 40° F., and the average annual precipitation is 40 inches.

Stand composition and structure before harvesting were largely the result of two major occurrences during the early part of this century—a commercial harvest around 1900 and spruce budworm mortality and salvage operations in the early 1920's. Dominant and codominant trees averaged 50 to 65 feet tall. The stand contained about 310 trees per acre, totaling 1,855 cubic feet of gross volume in trees 5.0 inches d.b.h. and larger. About 75 percent of the volume was red spruce (*Picea rubens* Sarg.), white spruce (*P. glauca* (Moench) Voss), and balsam fir (*Abies balsamea* (L.) Mill.). Associated softwoods and hardwoods accounted for the remaining 25 percent.

In the winter of 1965 to 66, parts of the stand and the lower portions of adjacent hardwood slopes were logged experimentally. A Beloit Tree-Harvester (fig.1) was used in the logging, and Beloit grapple skidders (fig. 2) were used

Figure 1.—The mechanical tree harvester in operation.

Figure 2.—A four-wheel rubber-tired skidder hauls a load of stems to a landing.

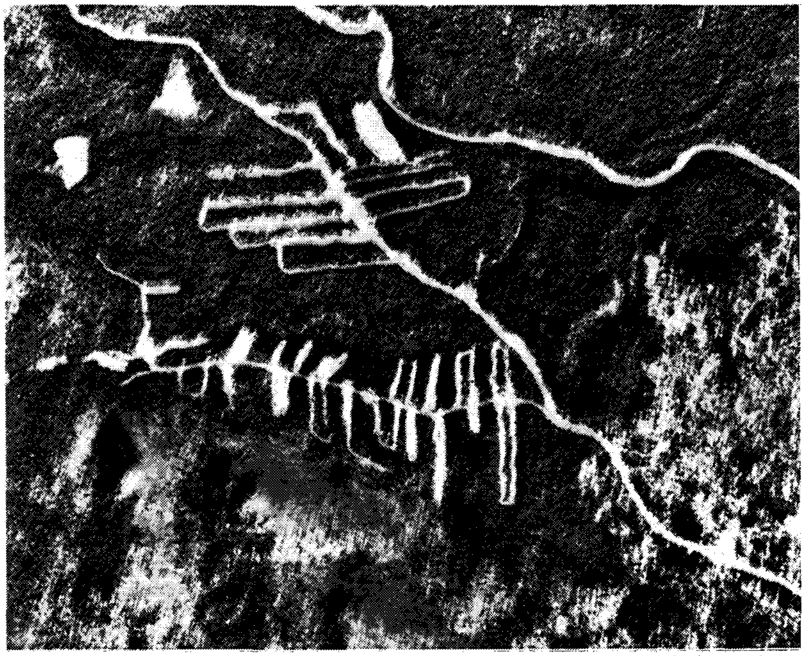

Figure 3.—An aerial view, showing the pattern of cleared strips.

to haul out the stems. (Mention of these products is for information only, and is not intended as an endorsement by the Forest Service or the U. S. Department of Agriculture.)

The timber was harvested in cleared strips (fig. 3).

PROCEDURES

To determine whether or not an adequate distribution of seedlings was present both before harvest and 1 and 2 years after harvest, rectangular ¼-milacre sample plots were installed in seven randomly selected cleared strips.

The plots were systematically distributed in portions of the seven strips, which varied in length from 300 to 1,300 feet. Strip widths were approximately 50, 100, and 200 feet. The strips were oriented in five directions, ranging from east-west to north-south.

There were 667 sample plots, each measuring 2.5 feet by 4.36 feet. Ninety of these were established 30 feet into the residual stand, adjacent to the cleared strips, for estimating the pre-harvest stocking. Locations of the 90 plots and the remaining 577 plots within the cleared strips were on transects evenly spaced along the portions of strips to be sampled. The number of transects per strip varied from 13 to 20, depending primarily on total length of the strip. All transects were more than 60 feet from a road, landing, or other clearing.

For strips 50 feet wide, each transect contained three plots —one at the center and one 10 feet from each edge. For strips wider than 50 feet, additional plots were installed 20 feet from each edge. Where necessary, plot locations were adjusted to have each plot represent only one combination of site conditions.

Site conditions at plot locations were recorded by (a) direct sunlight exposure class, (b) slash density class, and (c) logging area class.

Exposure classes were derived from the results of a study that illustrated the pattern of sunlight and shade in small forest clearings (*15*). Shade was defined as the open shade cast by trees along the borders of small clearings. Three exposure classes were used:

Minimum exposure— 0 to 20 percent of full sunlight.
Medium exposure —21 to 50 percent of full sunlight.
Maximum exposure—51 to 100 percent of full sunlight.

The measure of slash density was subjective. Three classes were recognized. Density was determined by the percentage of the plot surface visible from a point directly overhead. Density classes were:

Light slash—51 to 100 perecent of plot surface visible.
Moderate slash—26 to 50 percent of plot surface visible.
Heavy slash—0 to 25 percent of plot surface visible.

The differences in ground conditions caused by the passage of machines can influence seedling survival. Accordingly, two logging area classes were used:

On skid roads—plots located in areas in cleared strips displaying evidence of repeated machine passage.
Off skid roads—all other plots.

OBSERVATIONS

Plot establishment and initial observations were made during the fall of 1966, one growing season after logging. The second and final observations were made during the fall of 1967. Evidence has been reported elsewhere that 2 years is ample time in which to observe initial seedling survival after logging (*8*). Mortality is greatest during this period, and the rapid invasion of shrubs and other growth usually has not resulted in severe competition.

Observations on plots were limited to the presence or absence of seedlings of three species groups—spruce and fir, hardwoods, and all species combined. Size and vigor of the plant were not limiting criteria. The problem of defining an established or advance seedling remains elusive because even low-vigor seedlings on seemingly hostile sites do survive and develop into thrifty trees (*14*). For this study, a seedling was recorded if it was living and if it originated within the plot.

ANALYSIS

Plot means were based on the percent stocking of surviving seedlings observed on all plots (table 1). Also, partial data were analyzed to answer two questions. QUESTION 1: What is the lowest expected percent stocking 1 and 2 years after logging? A t-test for 5 percent probability was used to calculate half-confidence intervals for seedlings subjected to maximum exposure and to the various slash densities (table 2). QUESTION 2: Is there significant difference in mean percent stocking between skidroad and non-skidroad areas? Data were analyzed by analysis of variance.

Table 1.—Distribution of seedlings by species groups, exposure class, and slash density class, 1 and 2 years after harvest

Exposure class	Species group	Years since harvest	Slash density class: Heavy	Medium	Light	Mean percent stocking
		Years	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Minimum	Spruce and fir	1	50	60	86	69
		2	44	55	86	66
	Hardwoods	1	56	95	97	86
		2	31	80	93	74
	All species	1	62	100	100	91
		2	56	90	97	85
Moderate	Spruce and fir	1	51	83	78	75
		2	37	73	70	65
	Hardwoods	1	51	80	85	80
		2	31	81	77	70
	All species	1	65	98	92	89
		2	51	97	85	82
Maximum	Spruce and fir	1	60	85	82	76
		2	54	69	78	69
	Hardwoods	1	67	93	89	84
		2	44	73	77	67
	All species	1	79	95	97	96
		2	68	86	93	85
Mean percent stocking	Spruce and fir	1	55	80	80	74
		2	46	69	74	67
	Hardwoods	1	59	92	87	82
		2	38	78	78	69
	All species	1	72	97	94	90
		2	60	91	89	83

Table 2.—The percent stocking of surviving seedlings exposed to maximum direct sunlight, by species group slash density class, and years since harvest

Characteristics of sample populations					Lowest 10-percentile in which the true mean may be located[1]						
Species group	Slash density class	Years since harvest	Sample mean	Lower confidence limit	90	80	70	60	50	40	30
		Number	*Percent*	*Percent*							
All species	Light	1	98.2	92.2	*	—	—	—	—	—	—
		2	94.5	86.7	—	*	—	—	—	—	—
	Medium	1	96.9	85.5	—	*	—	—	—	—	—
		2	88.7	69.8	—	—	—	*	—	—	—
	Heavy	1	79.9	76.8	—	—	*	—	—	—	—
		2	67.6	58.7	—	—	—	—	*	—	—
Hardwoods	Light	1	93.9	86.8	—	*	—	—	—	—	—
		2	78.9	77.6	—	—	*	—	—	—	—
	Medium	1	94.3	86.2	—	*	—	—	—	—	—
		2	71.7	67.4	—	—	—	*	—	—	—
	Heavy	1	68.8	67.9	—	—	—	*	—	—	—
		2	48.8	48.0	—	—	—	—	—	*	—
Spruce and fir	Light	1	82.9	78.4	—	—	*	—	—	—	—
		2	79.1	72.6	—	—	*	—	—	—	—
	Medium	1	87.1	63.8	—	—	—	*	—	—	—
		2	68.4	45.7	—	—	—	—	—	*	—
	Heavy	1	58.2	44.2	—	—	—	—	—	*	—
		2	50.9	35.3	—	—	—	—	—	—	*

[1] Based on a probability of 0.95

RESULTS AND DISCUSSION

Seedling Characteristics Before Harvest

Observations made after logging in the adjacent undisturbed stand indicated that mean percent stocking was adequate in the cleared strips before logging. Seedling distribution was:

Species	*Stocking percent*
Spruce and fir	99
Hardwood	91
All species	100

Average height of the tallest spruce and balsam fir seedlings was estimated to be about 6 inches. The hardwoods included red maple (*Acer rubrum* L.), sugar maple (*A. saccharum* Marsh.), and yellow birch (*Betula alleghaniensis* Britton). The tallest hardwood seedlings were about 9 inches. An associated conifer, northern white-cedar (*Thuja occidentalis* L.) averaged less than 6 inches in height.

Most seedlings present at the time of harvest were less than 1 foot tall, and it is these smaller seedlings that are least susceptible to logging damage (*11, 19*). Many seedlings were afforded some protection by the snow cover, which exceeded 1 foot in depth (*12, 20*). Had the average seedling height been greater or the amount of snow less, the cover of snow might not have been protective at all. And the stocking figures after harvest might not have been so high.

Seedling Survival After Harvest

The tree-harvester created little discernible disturbance to the forest floor. As the machine moved from tree to tree, it "floated" on slash previously deposited. But compaction of slash did occur. Tree-length skidding with rubber-tired skidders created skidroads and even caused some windrowing of slash along these roads. Some disturbance to the forest floor—but very little soil disturbance—resulted from

Figure 4.—Compaction of slash in this cleared strip is still evident 1 year after harvesting.

skidder passage. These conditions remained visible after snow melt (fig. 4). This observation is similar to results reported for both summer and winter operations in spruce-fir forest types and for other kinds of logging systems (*2, 3, 9, 11, 19*).

Initial survival as expressed by percent stocking was good both 1 and 2 years after harvest (table 1). Overall losses during the first year, including an indeterminate amount of logging damage, resulted in a 10-percent reduction in mean stocking—from 100 percent to 90 percent. Losses during the second year amounted to a reduction of an additional 7 percent, to 83 percent stocking.

Spruce and fir losses exceeded hardwood losses, but only slightly. Mean percent stocking dropped from 99 percent before harvest to 74 percent and to 67 percent 1 and 2 years after harvest respectively. Comparable figures for hardwoods were 82 percent and 69 percent from a mean percent stocking of 91 percent before harvest. Thus the reductions in stocking at the end of 2 growing seasons were about one-third in spruce and fir and about one-quarter in hardwoods.

It is apparent that meaningful differences in survival were caused by variations in slash density. Specifically, it was the heavy accumlations of slash that caused maximum seedling mortality. Death was probably hastened by dense slash piles because they physically crushed seedlings and inhibited the penetration of both moisture and light to the seedbeds beneath (*1, 5, 10, 13, 16, 18, 21*).

Apparently precipitation was adequate and well distributed during both growing seasons. The near-normal amounts of moisture possibly prevented mortality among seedlings located within areas of maximum exposure. Adequate soil moisture conditions throughout the growing season can prevent critical moisture stresses within plant tissues (*7*). And with necessary rainfall, lethal air or surface soil temperatures are not likely to be reached even on seedbeds exposed to direct sunlight for long periods of time.

Two years after harvest, the mean stocking of spruce and fir under heavy slash accumulations and all exposure classes combined was 46 percent, or about one-third less than the other density classes. Hardwood stocking under similar conditions was about one-half that found in the less dense slash classes. Stocking was only 38 percent. And the mean stocking of all species under heavy slash, at 60 percent, was two-thirds that found in the other classes.

Lowest Expected Percent Stocking

Stocking of surviving seedlings 1 and 2 years after harvest on the portions of sample strips receiving maximum direct sunlight exposure was lowest for spruce and fir seedlings under heavy slash. Low stocking levels also occurred both for spruce and fir under medium slash and for hardwoods under heavy slash. All other stocking levels were good or extremely good. This analysis was based on data obtained from the four sample strips containing the necessary number of plots sufficient for statistical investigation.

The lowest confidence limit was 35.3 percent stocking for spruce and fir under heavy slash—the only lower limit to be included within the 30th percentile (table 2). Spruce and fir stocking under medium slash and hardwood stocking under heavy slash were both within the 40th percentile, with lower confidence limits of 45.7 percent stocking and 48.0 percent stocking respectively. No other combination of species and slash densities resulted in stocking levels below the 50th percentile at the end of 2 years.

Stocking levels under light slash were all high. The lowest stocking under light slash, recorded for spruce and fir, was within the 70th percentile.

Effect of Skidroads on Survival

Mechanical damage caused only minor to moderate reductions in stocking on logged areas classified as skidroads. Damage was estimated by comparing mean percent stocking of plots on skidroads with those off skidroads (fig. 5).

At the end of two growing seasons, reductions in stocking under light slash, the predominant slash density found on the skidroads, and under all exposures combined were 20.1 percent in spruce and fir, 6.8 percent in hardwoods, and 8.2 percent for all species.

The differences, within a species group, on on-skidroad and off-skidroad stocking levels did not change appreciably in 2 years. This indicates that seedling survival was not seriously affected by the differences in micro-environment caused by skidroads.

Statistically there were some significant differences in survival due to logging. Survival of spruce and fir and survival of all species was significantly less on skidroads both years. Differences were not significant for hardwoods either year. However, since the lowest stocking mean reported was above 60 percent on skidroads and above 80 percent off skidroads, the statistical significance is not very meaningful. It does indicate that machine passage during winter conditions does cause some mortality to the small seedlings present at time of harvest, but the amount is not critical.

RECOMMENDATIONS AND CONCLUSIONS

- The stocking of spruce and fir and hardwood seedlings under 1 foot in height was not seriously reduced by a wintertime Beloit Tree-Harvester operation in cleared strips. Surviving stocking is adequate for a period of at least 2 years after logging. These results were obtained in

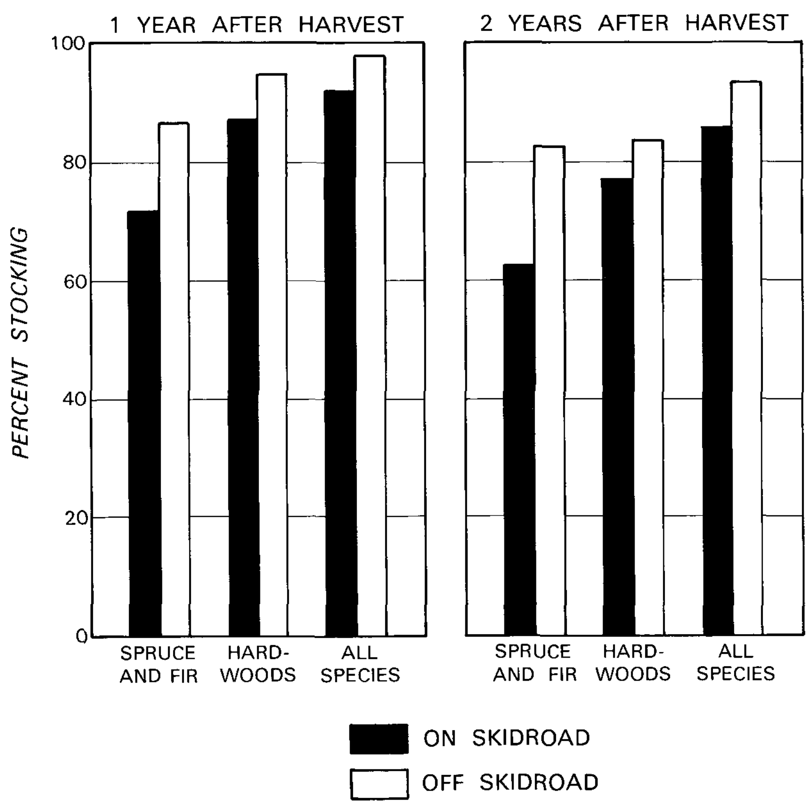

Figure 5.—The mean percent stocking of surviving seedlings 1 and 2 years after harvesting, under light slash and all exposures.

stands containing at least 50 percent spruce and fir by volume.

- Heavy slash accumulations create the least favorable site conditions for seedling survival. Until the benefits, if any, of dense piles of slash can be demonstrated, we recommend that heavy concentrations of slash be avoided.
- Since all the environmental factors that affect seedling survival in cleared strips were not measured in this study, we recommend that strip width not exceed 200 feet. Other workers suggest that narrow strips, preferably not exceeding one-half of stand height, be cleared if spruce and fir is to be favored over hardwoods.
- Length of strip probably will not be a factor in stocking of skidroads if total length does not exceed 1/4 mile. Repeated machine passage over skidroads in longer strips could result in excessive seedling damage and mortality. We therefore recommend that a second skidroad be established if strip length is greater than 1/4 mile. Not to be completely discounted are the potential beneficial aspects, as suggested by others, of skidroads receiving overuse on strips otherwise regenerating too densely.

The area in which this experiment was conducted was the location for the first trial of tree-length mechanical harvesting in the spruce-fir forests of the Northeast. Other equipment and other harvesting schemes have since been tested, and testing will no doubt continue until completely mechanical systems are developed. The cooperators strongly suggest that research monitor all aspects of machine operations as they relate to the natural as well as the artificial regenerative capacity of the spruce-fir forest. Left unanswered is the question of cultural treatments required within the cleared strips to hasten and ensure development of the desired new stand. Likewise, in either alternate or progressive strip operations, the timing of the harvest of an adjacent strip is also left unanswered.

The recommendations listed above are a beginning.

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