United States
Department of
Agriculture

Forest Service

Northeastern Forest Experiment Station

Research
Paper NE 498

1982

Effect of Advance Seedling Size and Vigor on Survival after Clearcutting

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Manuscript received for publication 20 February 1981

Abstract

In several separate experiments, it was found that survival of advance seedlings after clearcutting in Allegheny hardwood stands is a function of initial seedling size—larger seedlings survive best. Age, number of leaves, and leaf size also were important determinants of survival. In Allegheny hardwood stands, where advance regeneration is typically less than 1 foot in height, seedlings that are less than 1 or 2 inches tall, or that have fewer than two normal-size leaves, or that are 1 year old should not be considered as established in advance regeneration assessments. Advance seedlings that originated under a shelterwood canopy survived overstory removal much better than seedlings from an uncut stand. Therefore, the final removal cut of a shelterwood sequence can be made as soon as there are an adequate number of seedlings.

Introduction

Advance seedlings—those beneath the overstory canopy before cutting—play a major role in the regeneration that develops after clearcutting in many eastern hardwood types (Smith 1962; Sander and Clark 1971; Trimble 1973; Leak and Wilson 1958). If advance seedlings are not present before cutting, clearcutting often will fail to regenerate such species as the oaks, the maples, white ash, black cherry, and basswood. In recent years, guidelines have been developed to estimate the numbers of advance seedlings required before cutting to achieve satisfactory regeneration after cutting (Grisez and Peace 1973; Sander et al. 1976).

Size of the advance seedlings has an important effect on how well they survive and grow after cutting. In the oak types of the Central States, Sander (1972) found that oak seedlings less than 4.5 feet tall at the time of cutting do not contribute significantly to the future stand, because these small stems are overtopped by other faster growing competitors. Even larger advanced stems (2 to 6 inches dbh) may be required for sugar maple and beech to find a place in the main crown canopy of northern hardwood stands that also contain fast-growing intolerants such as black cherry (Marquis 1981).

But under other circumstances, much smaller advance seedlings may be adequate—where competition is sparse or the species desired are the fastest growing of those present. Such is the case in the Allegheny hardwood region of Pennsylvania, where deer browsing, dense canopies, and lack of seed of some species result in understory vegetation composed almost entirely of small black cherry and red maple seedlings. Although most of these seedlings live only 3 to 5 years and seldom exceed a height of 6 inches to 1 foot beneath a closed canopy, they grow quickly if released, and provide for the establishment of a new stand despite deer browsing if present in large numbers before cutting. Where absent, advance seedlings can often be established by a shelterwood seed cutting (Marquis et al 1975; Marquis 1979).

Although these comparatively small seedlings seem to respond well to clearcutting under current conditions on the Allegheny Plateau, it was not known whether this response held true for extremely young and extremely small seedlings. In making assessments of advance regeneration, we needed to know whether or not to count all ages, sizes, and species of seedlings equally, or whether some types survive poorly and should be ignored in the counts. Also, we needed to know how long it might take after the seed cut of a shelterwood sequence for seedlings to be well enough established to survive the final removal cut. To provide information needed to answer these questions, two experiments were established to determine the characteristics of seedlings that survive clearcutting.

Study Methods

In the first experiment, advance seedlings of seven species were located and marked in seven separate stands scheduled for clearcutting on the Allegheny National Forest. Attempts were made to secure seedlings covering a range of size, age, and vigor. At the time of installation, the species, height, length of shoot growth for the current year, number of leaves, length of the longest leaf, and shoot age were recorded. Shoot age was determined as accurately as possible from counts of bud scale scars.

Five of the seven stands were cut during the dormant season; the remaining two were cut during the growing season. One full growing season after clearcutting of the overstory, the seedlings were remeasured to determine survival. Over half of the more than 1,300 seedlings originally measured were lost to logging damage. Results are based on 547 seedlings that were relocated successfully after logging. Chi-square tests of homogeneity were used to determine differences in the proportion of surviving seedlings for black cherry, sugar maple, and red maple. There were too few seedlings of the other four species to make meaningful tests, but data from these species are included to show trends.

Because the range in seedling size and age beneath most Allegheny hardwood stands is limited, a second experiment was established where initial size and age could be more carefully controlled. About 500 8-inch diameter flower pots were filled with a mixture that was two-thirds forest soils (rototilled) and one-third sand. These pots were buried flush with the ground in a 55-year-old stand on the Kane Experiment Forest. Half of the pots were located beneath an uncut portion of the stand, and half beneath a portion of the stand from which two-thirds of the basal area had been cut (heavy shelterwood seed cut—see Marquis 1979 for details on the stand and cutting treatments). Seeds of black cherry, sugar maple, red maple, and white ash were sowed in the pots in the fall of 1971. During July of 1972, 10 pots of each species from each initial environment were moved to an adjacent clearcut area and were again buried flush with the soil surface. Seedlings were thinned to a maximum of eight per pot at the time they were moved.

Similar groups of 80 pots were moved to the clearcut in October 1972, July 1973, October 1973, July 1974, and October 1974, providing six movement dates, each representing seedlings of different sizes and ages. Height and root collar diameter were recorded for each seedling at the time of movement, and again after each of the first two full growing seasons thereafter. The objective was to observe survival and growth after release of seedlings of six different age or size classes, after an initial establishment period under either an uncut or shelterwood environment. Movement of pots in July and October also simulated cutting during the growing and dormant seasons.

Differences among treatment means were tested by analyses of variance and covariance after arcsine transformation for survival rates. Least squares regression techniques were used to relate initial seedling size to survival. Survival rates are the proportion of the original seedlings (usually eight) in each pot still alive after 2 years. Growth is based on the largest individual in each pot over the 2-year period after movement to the clearcut.

Results

Experiment 1

In the first experiment, survival of the various species ranged from 38 to 80 percent. Larger seedlings of all species generally survived better than smaller ones. Initial height was a significant variable for black cherry, red maple, and sugar maple. Initial number of leaves was significant for black cherry, and length of longest leaf was significant for black cherry, red maple, and sugar maple. The other species also followed these general patterns (Table 1).

In general, older seedlings survived better than younger ones; differences were statistically significant for red maple and sugar maple. Initial vigor, as measured by shoot growth during the year before cutting, was significant for red maple and sugar maple, but sugar maple seedlings with the greatest growth had the poorest survival. Thus, initial shoot growth is apparently a poor indicator of survival after clearcutting under these conditions.

Because of these significant differences, it seemed possible that initial height, numbers of leaves, length of longest leaf, age, and similar characteristics might prove useful in identifying seedling classes with markedly different survival. To explore these possibilities, data for each species were examined and segregated into several classes on the basis of survival. These groupings illustrate the range in survival obtained at various levels of the initial seedling characteristics, and suggest ranges that could be validated with additional data (Table 2).

There were no consistent differences in survival between areas clearcut during the growing season and areas clearcut during the dormant season.

Table 1.—Precutting characteristics of advance seedlings that died or survived clearcutting in Experiment 1.

Item	Height	Number of leaves	Length largest leaf	Age	Previous year shoot growth	Number in sample	Percent survival
	Inches		*Inches*	*Years*	*Inches*		
Black cherry[a]							
Died	2.6	3.2	1.6	3.3	0.8	36	
Survived	4.2	5.2	2.0	4.0	1.0	122	77
Red maple[a]							
Died	2.3	3.5	1.0	3.0	1.2	84	
Survived	2.8	3.5	1.4	4.1	0.9	101	55
Sugar maple[a]							
Died	2.6	2.1	1.5	2.0	1.9	76	
Survived	3.2	2.2	2.0	3.7	1.3	45	37
White ash[b]							
Died	3.0	3.5	1.8	4.0	0.6	2	
Survived	5.3	8.4	3.2	4.4	1.1	8	80
Beech[b]							
Died	7.2	5.0	2.8	3.3	2.4	8	
Survived	12.2	17.9	3.4	5.9	2.3	18	69
Birch[b]							
Died	2.0	3.9	1.2	2.0	1.0	8	
Survived	4.0	9.0	2.2	2.5	2.4	5	38
Striped maple[b]							
Died	2.9	2.6	2.4	4.6	1.0	10	
Survived	3.6	2.0	3.0	6.1	.8	14	58

[a] Means not connected by a line are statistically different at the 0.05 level.
[b] The small sample sizes for these species do not provide an adequate basis for evaluating results. Results of statistical tests are not shown.

Table 2.—Percent survival as a function of initial characteristics, Experiment 1.

Characteristic	Black cherry	Red maple	Sugar maple
Height			
0–2 inches	58	44	0
2–6 inches	74	58	49
6 inches +	100	100	100
Number of leaves			
1–2	65	51	37
3–5	77	56	38
6 +	100	47	—
Length of longest leaf			
0–1 inch	79	31	24
1–2 inches	71	61	26
2 inches +	88	90	71
Age			
1 year	78	40	24
2 to 4 years	74	56	25
5 years +	82	69	61

Experiment 2

An outbreak of cherry scallop-shell moth in 1972 affected nearly all of the black cherry seedlings in this experiment, causing mortality on some and apparently reducing the vigor and growth of those that survived. Thus, black cherry responses must be interpreted with this insect damage in mind.

As a result of the dense shade in the uncut stand, no seedlings of black cherry, red maple, or white ash survived through the entire third growing season there, so there were no seedlings of these species to move to the clearcut in October 1974 from the uncut stand. Only sugar maple survived for the 3 full years under these conditions. All four species survived for the 3-year period under the two-thirds cut, so there are no missing data for these treatments.

All of the pots moved to the clearcut during the first 2 years had eight seedlings, but some of those from the uncut stand during year 3 had less than eight. There were no significant differences in seedling size among pots prior to movement as a result of seedling density, nor were there significant differences in growth after movement to the clearcut as a result of differences in seedling density.

Effect of Initial Environment and Age on Survival

The most obvious and striking result of this experiment is that seedlings started in the two-thirds-cut stand survived far better after being moved to the clearcut than did seedlings started in the uncut stand. Differences were significant for all four species at the 0.01 level. Of the four species, sugar maple differed the least between the two initial environments. Sugar maple seedlings started in the uncut stand survived nearly as well as those started in the two-thirds cut, and survival of sugar maple seedlings started in the uncut stand was much higher than survival of the other species from that stand (Table 3).

Table 3.—Percent survival 2 years after being moved to the clearcut as a function of initial environment, Experiment 2[a]

Species	Initial environment	
	Uncut	two-thirds cut
Black cherry	12	70
Sugar maple	78	97
Red maple	26	91
White ash	38	99

[a] Differences among initial environments statistically significant at 0.01 level for all four species.

Seedlings from the two-thirds cut were larger than seedlings from the uncut stand when they were moved to the clearcut, particularly for seedlings 2 or 3 years old at the time of movement (Appendix). Thus, the differences in survival between seedlings started in the uncut stand and those started in the two-thirds cut might be attributed to size differences rather than to initial environment.

To test this possibility, covariance analyses were run to test differences in survival between the uncut stand and the two-thirds cut, using either initial height or initial diameter as the covariate. Results of these tests showed that differences in survival between the uncut and two-thirds-cut stands were significant—even after accounting for initial size—for black cherry, red maple, and white ash; differences in survival were not significant for sugar maple after covariance adjustment.

The reason for better survival of seedlings started in the two-thirds cut is not clear, but may be the result of differences in root-shoot ratio between seedlings grown in dense shade and those in moderately high light. Dense shade reduces root development much more severely than it does shoot development (Logan 1965; Marquis 1966). So the seedlings grown in the shade of the uncut stand probably had relatively small roots and were not as well equipped to meet the greatly increased transpiration demand after being moved to the clearcut. By constrast, those seedlings from the two-thirds cut probably had relatively large roots, and did not suffer so much from the increased moisture stress.

This hypothesis seems to fit the differences in response by species as well. Sugar maple, a tolerant species, is much less affected in root growth by dense shade, and as previously noted, sugar maple from the uncut stand survived appreciably better than seedlings of other species from that stand.

Interrelations Between Age and Initial Environment on Survival

Survival was better in the older and larger seedlings, but only for seedlings that started in the uncut stand (Table 4). One-year-old seedlings from the uncut stand survived poorly, and survival of seedlings from there improved the older they were when moved. By contrast, seedlings started in the two-thirds-cut stand survived well (over 90 percent in most cases), even if moved to the clearcut while only a few months old (Table 4).

Effect of Initial Size on Survival

Regressions of survival as a function of both initial height and initial diameter were calculated and tables were computed from these regressions showing the seedling size required to achieve 25, 50, 75, and 100 percent survival (Table 5).

Effect of Season Moved to Clearcut on Survival

Differences in survival between seedlings moved to the clearcut in July and those moved in October, as shown in the following tabulation, were not statistically significant. There was a tendency for leaves of seedlings moved in July to turn brown after being moved to the clearcut, but a new set of leaves usually developed the same year, and there was no obvious effect on survival.

Table 4.—Percent survival after 2 years in clearcut as a function of age and initial environment

Age when moved to clearcut (years)	Initial environment: Uncut	Initial environment: Two-thirds cut
BLACK CHERRY[a]		
1	12	51
2	17	68
3	—	90
SUGAR MAPLE		
1	63	98
2	79	98
3	91	97
RED MAPLE		
1	22	97
2	28	81
3	33	95
WHITE ASH		
1	38	99
2	51	98
3	—	99

[a] Survival of cherry reduced in early years due to insect defoliation.

Month	*Percent survival Uncut*	*Percent survival 2/3 cut*
July	38	92
October	38	87

Effect of Season Moved to Clearcut on Height Growth

Season of year in which the seedlings were moved to the clearcut did have a significant effect on growth, and the effect was different depending on the initial environment (Table 6). In general, seedlings that started under the two-thirds cut exhibited greater growth if moved to the clearcut in July rather than in October. This is probably due to a longer growth period (2-1/2 growing seasons for the July move, rather than two seasons for the October move) in the full sunlight of the clearcut. These seedlings from the two-thirds cut had about 50 percent of full sunlight before being moved to the clearcut, and there was probably little physiological shock involved in this move.

By contrast, seedlings from the uncut stand grew better if moved to the clearcut in October rather than July, despite the fact that the October move allowed less time in the open for growth to accumulate. Seedlings started in the uncut stand had only about 10 percent of full sunlight, had leaves typical of those on shade-grown plants, and seemed to suffer some physiological shock (leaves turning partially or completely brown, followed in some cases by refoliation) when moved to the clearcut in the middle of the growing season. Those moved after leaf fall in October did not appear to suffer, and produced typical sun-leaves the following spring. This shock of being moved in the middle of the season is probably responsible for the decreased growth of seedlings from the uncut stand, even though survival was not significantly affected.

Table 5.—Estimated seedling sizes required to obtain various survival rates 2 years after moving seedlings to clearcut

Percent survival	Black cherry Height	Black cherry Diameter	Sugar maple Height	Sugar maple Diameter	Red maple Height	Red maple Diameter	White ash Height	White ash Diameter
	Feet	*Inches*	*Feet*	*Inches*	*Feet*	*Inches*	*Feet*	*Inches*
25	0.2	0.04	0.2	0.03	0.1	0.02	0.1	0.02
50	.2	.05	.2	.04	.2	.03	.2	.04
75	.3	.06	.2	.06	.3	.05	.3	.06
100	.4	.08	.7	.10	.7	.08	.6	.10

Table 6.—Height and diameter growth of seedlings from uncut and two-thirds-cut stands after 2 years in clearcut[a]

Species	Uncut		Two-thirds cut	
	Height	Diameter	Height	Diameter
	Feet	*Inches*	*Feet*	*Inches*
Black cherry				
July	0.56	0.108	0.39	0.044
October	1.72	.160	.27	.026
Sugar maple				
July	.13	.066	.65	.084
October	.31	.074	.38	.054
Red maple				
July	.48	.099	.73	.109
October	.25	.049	.62	.092
White ash				
July	.44	.135	.91	.169
October	.62	.144	.65	.121
All species				
July	.40	.102	.67	.102
October	.73	.107	.48	.099

[a] Means not connected by a line are statistically different at the 0.05 level.

Seedling Characteristics and Survival

Both experiments provide information on the survival of advance seedlings after clearcutting as a function of initial size, age, or other characteristics. In general, the two experiments agree quite well, though there are differences in the kinds of data available from each. I have subjectively reconciled results of the two studies to provide a guide to the expected survival of advance seedlings (Table 7).

First, it seems apparent that very small or very young seedlings of most species have poor survival. Seedlings less than 1 or 2 inches tall, or that have fewer than two leaves of normal size, or that are 1 year old should not be considered in assessments of advance regeneration.

Second, seedlings larger than 6 inches tall survive appreciably better than seedlings in the 2- to 6-inch size class. Therefore, fewer seedlings would be required for adequate advance regeneration if the seedlings are more than 6 inches tall.

When making advance regeneration assessments in Allegheny hardwood stands in Pennsylvania, I recommend the following (see size-class definitions in Table 7):

Tiny—do not count
Small—Count each seedling as 1
Medium-size black cherry—count each seedling as 1-1/2
Medium-size other desirable species—count each seedling as 2

Thus, minimum stocking of advance regeneration on a 6-foot radium plot is 25 black cherry or 100 of all desirable species by current guidelines if all seedlings are small (Marquis and Bjorkbom, 1982). If some or all are larger, adequate stocking will be achieved with fewer seedlings.

Conclusions

Survival after clearcutting is affected by initial size of advance seedlings, even in the Allegheny hardwood type of Pennsylvania where almost all seedlings are less than 1 foot tall. Very tiny seedlings (less than 1 to 2 inches tall, or that have less than two normal-size leaves, or that are 1 year old) survive poorly and should not be considered as established in advance regeneration assessments. Seedlings more than 6 inches tall survive appreciably better than seedlings in the 2- to 6-inch size class.

Seedlings started under a heavy shelterwood canopy survived exposure to full sunlight much better than seedlings started in an uncut stand. The effect of initial cutting level was more important for intolerant black cherry, white ash, and red maple than for tolerant sugar maple. Age or size of seedlings was a much more important determinant of survival for seedlings from the uncut stand than for those from a heavy shelterwood cut.

Table 7.—Estimated survival rates (2 years after final harvest) for three size classes of Allegheny hardwood seedlings, in percent

Size class[a]	Black cherry	Sugar maple	Red maple	White ash	Beech	Birch
Tiny	33	0	0	25	25	0
Small	67	33	33	50	50	33
Medium	100	67	67	100	100	67

[a] Tiny: less than 2 inches tall, or fewer than two normal-size leaves for the species, or current-year seedling (as evidenced by visible cotyledons or primary leaves; Small: 2 to 6 inches tall with at least two normal-size leaves; Medium: more than 6 inches tall with numerous normal-size leaves.

Exposure to full sunlight during the middle of the growing season caused browning of leaves and some defoliation on seedlings started under the dense shade of the uncut stand. Although this did not result in significantly lower survival, it did reduce growth of these seedlings. Seedlings started in the light shade of the heavy shelterwood cut did not exhibit such effects.

Advance seedlings in previously uncut stands should achieve 3 or 4 years of age and 4 to 6 inches in height (or more) for best survival after clearcutting. Younger or smaller seedlings will not survive as well. Advance seedlings developed under heavy shelterwood cutting will survive and grow well even during the first year. The final removal cut can, therefore, be made as soon as the desired number of seedlings are present.

Conclusions drawn here are based on initial survival after clearcutting, and do not necessarily imply that all species and sizes that survive initially will assume an important position in the next stand. Large differences in growth rates will undoubtedly relegate slower growing species to the understory, as described in the introduction. So perpetuation of the slower growing species in the main crown canopy of the next stand may require much larger advance stems than implied here.

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Appendix

Table 8.—Initial height and diameter of seedlings from uncut and two-thirds-cut stands at the time of movement to clearcut

Age when moved to clearcut (years)	Uncut		Two-thirds cut	
	Height	Diameter	Height	Diameter
	Feet	*Inches*	*Feet*	*Inches*
		BLACK CHERRY		
1	0.20	0.036	0.21	0.056
2	.21	.035	.22	.055
3	—	—	.28	.067
		SUGAR MAPLE		
1	.25	.062	.21	.072
2	.28	.064	.34	.095
3	.35	.074	.53	.113
		RED MAPLE		
1	.13	.037	.16	.041
2	.16	.029	.25	.046
3	.22	.037	.34	.067
		WHITE ASH		
1	.15	.041	.18	.056
2	.15	.035	.39	.082
3	.18	.040	.61	.114

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Survival of advance seedlings after clearcutting in Allegheny hardwood stands is a function of initial seedling size—larger seedlings survive best. Age, number of leaves, and leaf size were also important determinants of survival. Advance seedlings that originated under a shelterwood canopy survived overstory removal much better than seedlings from an uncut stand. Therefore, the final removal cut of a shelterwood sequence can be made as soon as there are an adequate number of seedlings.

231.1:221.1—176.1(748)

Keywords: Allegheny hardwoods; clearcutting; advance regeneration

☆U.S. GOVERNMENT PRINTING OFFICE: 1982-505-012:16

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