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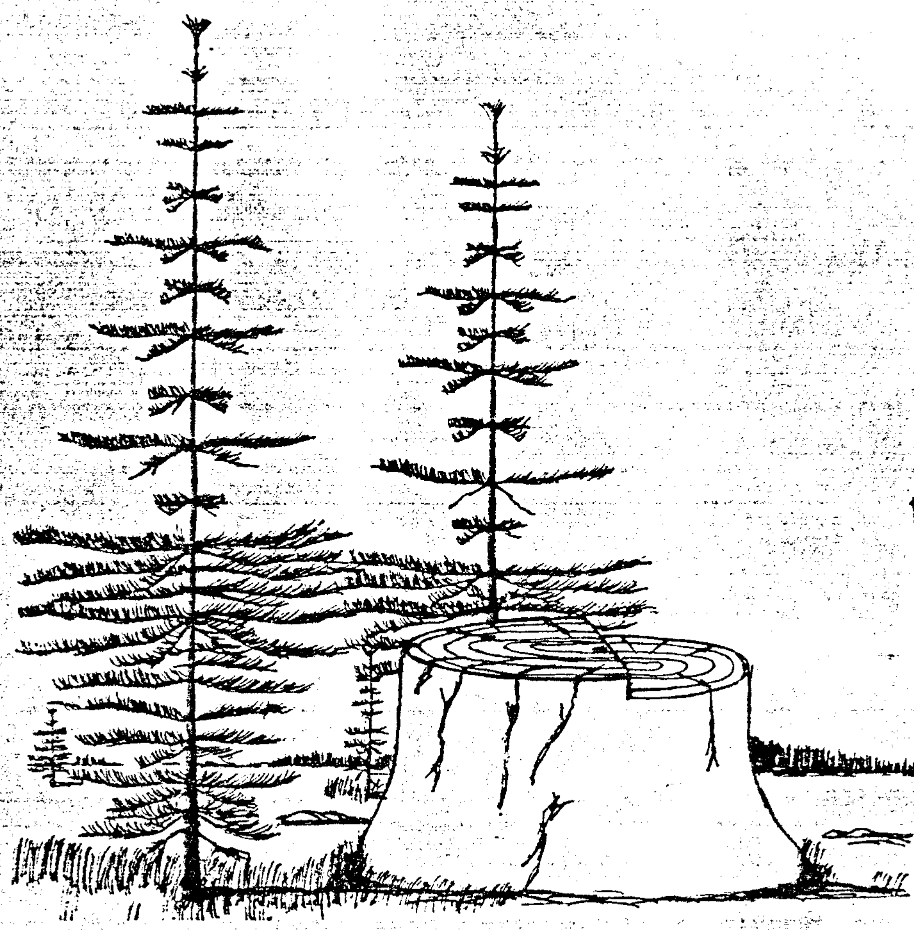

Released advance reproduction of white and red fir. . . growth, damage, mortality

Donald T. Gordon

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CONTENTS

The Author

DONALD T. GORDON is doing research on the silviculture of Sierra Nevada forest types, with headquarters at Redding, Calif. Native of Oxnard, Calif., he was educated at the University of California, Berkeley (B.S. in forestry, 1939), and joined the U.S. Forest Service in 1940. He became a member of the Station's staff in 1946.

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SUMMARY

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1973 **Released advance reproduction of white and red fir . . . growth, damage, mortality.** Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif. 12 p., illus. (USDA Forest Serv. Res. Paper PSW-95)

Oxford: 243:231.1:181.65 [+ 174.7 *Abies concolor* + 174.7 *Abies magnifica*].

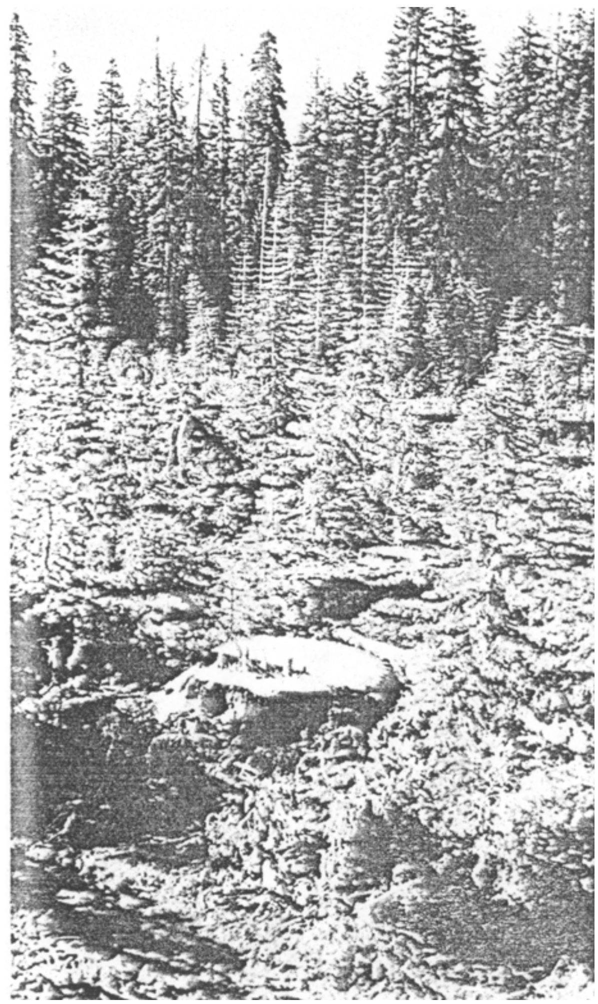
Retrieval Terms: Abies concolor: Abies magnifica; advance growth; liberation cutting; growth response; Swain Mountain Experimental Forest.

The scant early literature mentioning small white and red fir trees indicated without qualification that slow growth could be expected for the first 30 or 40 years. Such a characteristic would seriously lengthen rotations of these important conifers. At the Swain Mountain Experimental Forest, in northern California, the response of advance reproduction of both species to complete removal of a scattered overmature overstory was measured for several years.

A good general response in height growth rate was not apparent until the fifth year after release. Then, both white and red fir advance reproduction responded well. Dominant trees of the advance reproduction retained their relative crown positions. Some trees which initially had been less than 4.5 feet tall increased their annual height growth from 0.1 or 0.2 foot to about 1 foot. A few trees that had been 4 to 8 inches d.b.h. at time of release were consistently adding growth rings 3/8- to ½-inch wide at stump height.

Damage to the young trees was caused principally by logging, with snow and ice ranking next in importance. Logging damage, however, caused only 18 percent of mortality. Obvious or suspected effects of drought and competition accounted for most recorded mortality, and this occurred mostly among the smallest trees. On a 17-acre release cutting, advance reproduction stocking was entirely adequate at the end of the study.

The results of this study should generally have wide application in the management of true firs in the Sierra Nevada and southern Cascade Range.



Since 1958, the Pacific Southwest Forest and Range Experiment Station has been investigating the silvicultural management of true firs at its Swain Mountain Experimental Forest, in northeastern California. A number of experimental cuttings were made on the Forest. The research included studies of released white fir *(Abies concolor* [Gord. & Glend.] Lindl.*)* and red fir *(A. magnifica* A. Murray*)* understory, and of natural regeneration after logging. In an earlier report, I described several factors that affected natural regeneration (Gordon 1970). A later report deals with wind damage in stands of overmature white fir and red fir bordering clearcuttings (Gordon 1973).

The Swain Mountain Experimental Forest is about 10 miles north of Lake Almanor, at the southern limit of the Cascade Range. Elevations range from 5,700 to 7,054 feet. The forest cover is essentially pure fir, with white fir predominating at low elevations, red fir appearing almost exclusively at high elevations. Scattered sparingly over the Forest are small patches of lodgepole pine *(Pinus contorta* Dougl.*)*. These apparently became established after lightning fires. A fir understory often is present beneath this pine, or fir already has overtopped and is eliminating the pine.

Soil is derived from vesicular andesite and is 3 to 8 feet deep over most of the area. Rocks vary in size and abundance.

Precipitation falls mainly as snow during winter. Since 1957-58, a water equivalent of 40 to 50 inches a year usually has been recorded. Monthly surveys during four winters showed that maximum snow depth ranges between 8 and 10 feet. Study areas are in Site Class II (Dunning 1942), with dominant trees averaging 150 feet high at 300 years or 65 feet at 50 years. Site on the Experimental Forest is unusually uniform.

Stand structure varies widely. Gross volume of 147,000 board feet (Scribner) per acre has been recorded for commonly occurring dense old-growth stands. Until they begin to deteriorate, such stands prevent establishment of understory. Volumes of 60,000 to 80,000 board feet per acre are more usual in stands with some crown and age differentiation. All areas where only scattered old trees remain are covered with abundant advance reproduction *(fig. 1)*.

This paper reports a 7-year study of growth, damage, and mortality in released advance reproduction of white and red fir at the Experimental Forest. The cutting areas from which basic data were derived are few and on slopes of a single mountain. And they sample only a small range of possible residual conditions. Therefore, some results should be considered as examples or trends, rather than as average or typical. Other results, however–particularly those of physiological response–should have wide application in the management of true firs in the Sierra Nevada and southern Cascade Range.

METHODS

Early interest at Swain Mountain was centered on post-logging natural regeneration. Consequently, most data reported here on advance reproduction were gathered concurrently with those on new natural seedlings. Study areas were prepared by tractor logging all merchantable trees from (a) 3- and 5-chain wide strips in areas of dense old-growth and (b) irregularly shaped blocks conforming to areas supporting less dense old-growth with abundant understory. Size of the understory release blocks ranged from about 8 to 40 acres. Only one block was sampled, while three strips were studied.

Most data (76 percent) for this study were derived from a 17-chain long strip of square milacres running from edge to edge of an irregularly shaped block cut to release advance reproduction. The transect was installed nearly perpendicular to most skid trails. An average of 28 trees and 55,480 board feet (gross) per acre had been harvested from the block. Logging was supervised closely to insure minimum damage to advance reproduction.

The northwest-southeast oriented clearcut strips were prepared principally for observing factors influencing establishment of natural regeneration. One

Figure 1—Advance reproduction of white fir and red fir was released by experimental cuttings at the Swain Mountain Experimental Forest, northeastern California.

3-chain and two 5-chain wide strips contributed a small amount of data to this study. Strips were sampled by three milacre transects located within areas prepared to represent three different slash treatments. Because of original condition and disturbance by logging and slash treatments, only a few small groups and isolated trees of advance reproduction remained on the strips.

Data for the main body of study of regeneration and of release were gathered from a permanent system of continuous transects of square milacre plots. Transects ran across strips rather than parallel to cutting edges. All transects were oriented northeast-southwest, and on strips had limited random starts within slash treatment areas.

Initial observations on transects were recorded early in the two summers of installation (1959, 1960). These followed cutting by nearly a year. All areas were reexamined in fall 1960 and annually–except in 1962–through 1965..

Slopes recorded on study areas were 10 percent or less. All aspects were northeast. These two site factors were not included in any analyses.

For each milacre, these observations, as pertinent, for advance reproduction were recorded:

1. Species.
2. Number of stems.
3. Height class, by 1-foot intervals up to 10 feet.
4. Diameter for trees over 10 feet high, by 1-inch classes to 12 inches, and by 2-inch classes for larger trees.
5. Damage.
   a. Logging damage (15 specific types).
   b. Dwarf mistletoe (presence in bole or branches or both).
   c. Disease, excluding dwarf mistletoe ("snow fungus," etc.).
   d. Insects.
   e. Weather (sun, snow or ice, temperature, etc.).
   f. All other (defective form, browsing, bark damage by animals, etc.).
6. Cause of death, primary and secondary, by classes a-f above, and "unknown."

In the first examination only trees having some live needles were tallied. The few trees already dead could only be categorized with trees torn out during logging, and of course there was no record of the latter.

Diameter and height were not measured each year. Instead, trees were carried in their original size classes until the last remeasurement in 1965. Annual mortality or damage during the period of observation was assigned to the original size classes.

For another part of the study, age and annual height and diameter growth rates of a few small trees were recorded in 1969. Only 56 trees were included in the sample; half were white fir, and half red fir. Individual trees were selected for measurement within some 1958-60 cutting units not otherwise sampled. Selection was based on (a) density of seedling- or sapling-size advance reproduction around a chosen tree, and on (b) presence or absence of nearby poles or slightly larger trees (to about 16 inches d.b.h.) which might function as a competitive "overstory." Stem density ratings around sample trees were subjective. They were based on (a) previously observed growth reactions along some of the milacre transects, and (b) on professional judgment formed from observations within the Experimental Forest. No estimate of number of stems or of basal area per acre can be given. For the sample trees, total heights to branch whorls were measured in feet and tenths. Then, since most trees had been less than 4½ feet high at time of release, all were cut at ground level and a ½-inch-thick disk was cut from the severed end of each stem to determine total age and radial growth rate.

RESULTS

Stem Frequencies

Small released trees were not expected to die in vast numbers, and they did not. But we were concerned about another possibility: Would these true fir stands respond significantly to release?

For 4 years after release few trees in this study showed appreciable increase in annual height growth. In the fifth year after release, however, most trees began to grow faster than before. An important effect of release had become apparent–trees with dominant crown positions continued to retain their relative dominance. The results suggest that young fir trees on good sites only need growing space for relatively rapid growth; they require freedom from competing trees of larger size class.

Initially 827 trees classed as advance reproduction were found on sample milacres: 351 white firs, 452 red firs, and 24 lodgepole pines. Stem frequency per unit of area followed the usual pattern of decreasing numbers as sizes increased.

The relative number of stems by size classes was not significantly different statistically for white and red fir at the beginning of the study–except for the height class "less than 1 foot." Red fir had a greater initial relative frequency in that smallest class. During the study, however, mortality was proportionately greater there than for white fir, and proportionately more red fir grew into the 2-foot (and probably taller) height class. Seven years after release, differences in size class frequencies of the two fir species *(fig. 2)* still were statistically not significant.

Many tree stems within the 1-foot height class were spindly and bore few needles–especially those in heavily shaded locations. All trees were several years old. And 61 percent of all red fir mortality and 44 percent of white fir mortality occurred in this size class.

Net change in stem count, by size classes, was affected both by mortality and growth during the study. Fewer trees died than moved into larger size classes. The net effect was to increase frequencies in several classes, but not the smallest *(figs. 2, 3)*.

Stocking

Trees on the most densely stocked milacres would be expected to have the lowest survival rate because of competition for moisture, nutrients, and light. Results in this study show that this was not completely true *(fig. 4)*.

On the irregularly shaped block, the most densely stocked milacres had high survival rates *(fig. 5).* Part of the reason for this anomaly is the nearly flat soil moisture drainage area crossing the transect from the 10- to 12-chain point to the 17-chain point. In most years shaded soil surface there appears damp until midgrowing season.

Availability of soil moisture also explains the persistence of post-logging seedlings on the densely stocked areas during the study period. However, mortality rates for smallest trees indicate that most of these new seedlings will eventually die from competition–just as they do beneath densely stocked mature stands.

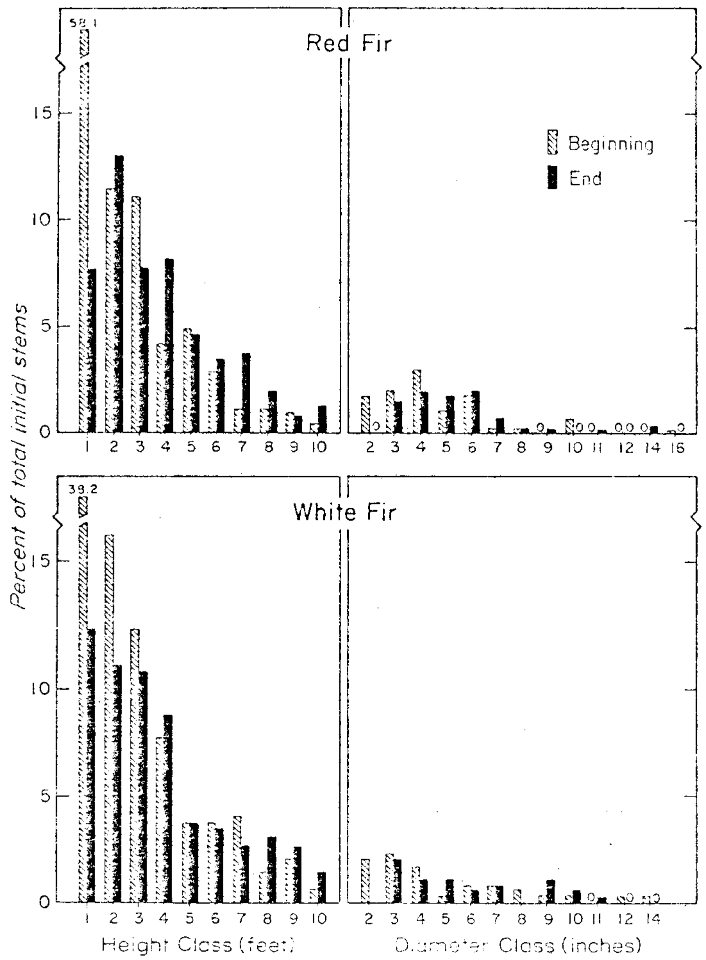


Figure 2—Size class frequencies of white and red fir during the 7 years of study at Swain Mountain Experimental Forest were essentially similar.

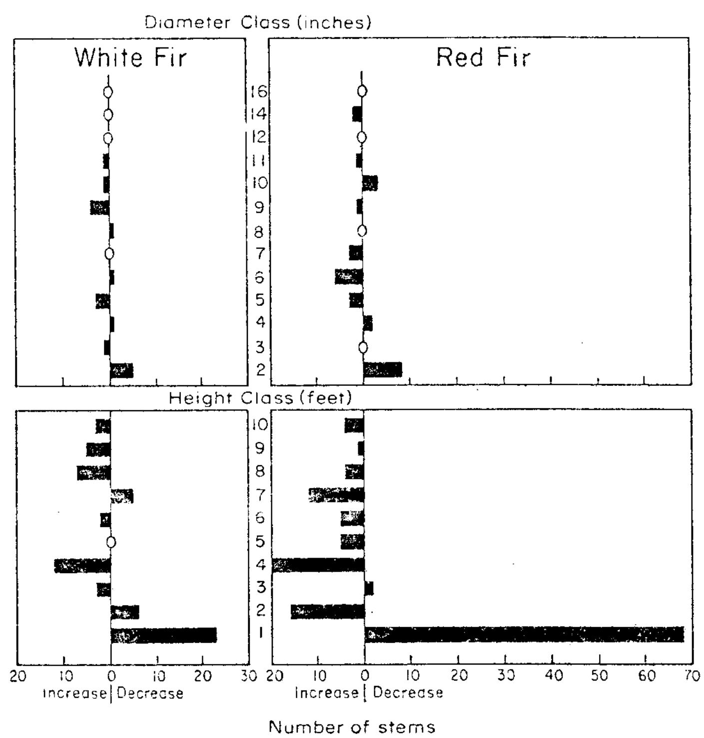


Figure 3—Net changes in size class frequencies clearly show that mortality and growth effects were concentrated in smallest trees during a 7-year study at Swain Mountain Experimental Forest.

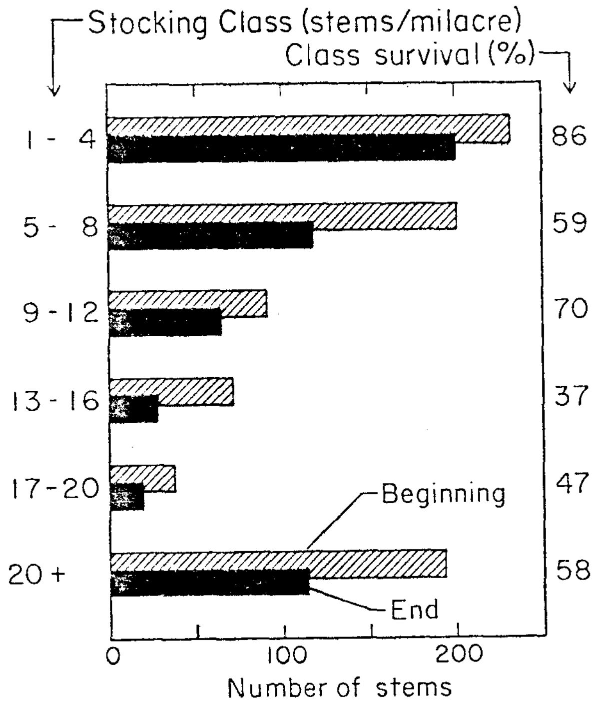


Figure 4—Survival of released advance reproduction followed no consistent pattern governed by density of stocking during the 7-year study period at Swain Mountain Experimental Forest.

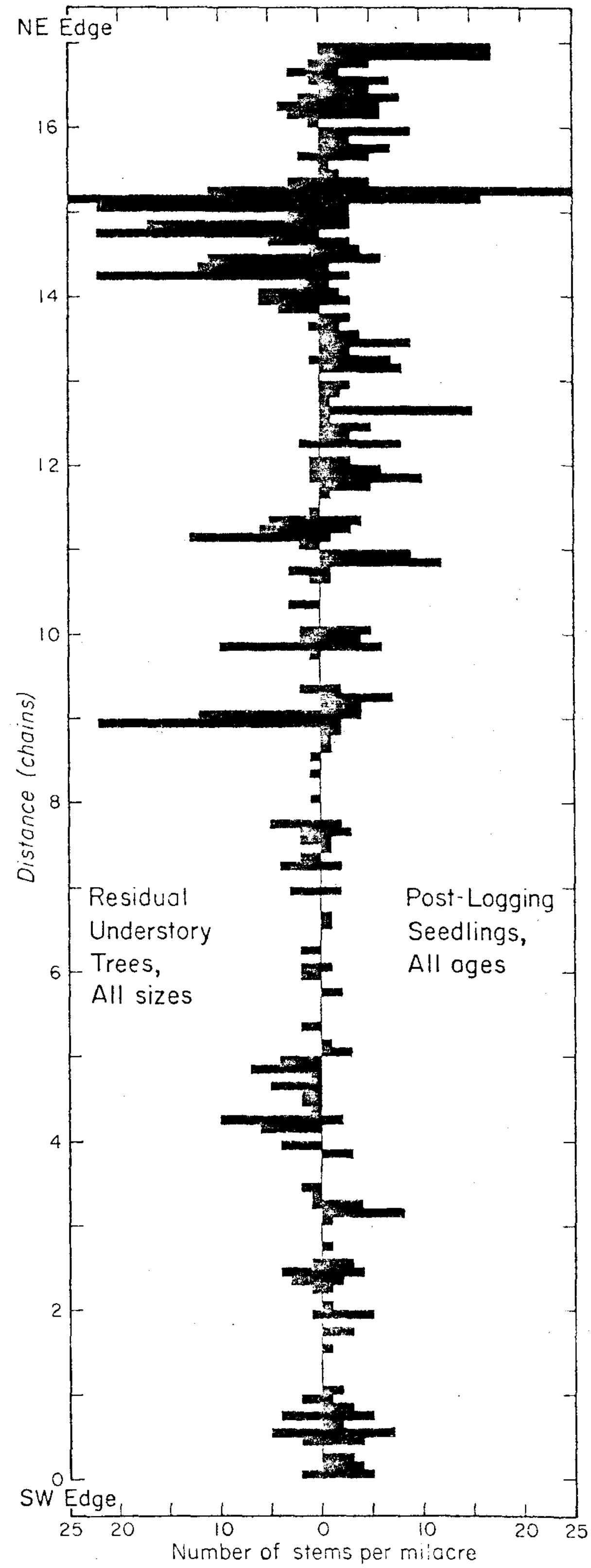


Figure 5—On a 17-chain long transect, milacres with densest stocking of residual understory trees also had most post logging seedlings 7 years after logging. A few large pole-size trees near the transect produced the seeds which generated new seedlings shown on the lower left part of the illustration.

Table 1–Sources *and kinds of damage and mortality*[1] *of affected trees, all study areas, by number of observations and of trees, Swain Mountain Experimental Forest, California*

Sources and kinds of damage	Observations[2] First	Observations[2] Final	Trees that died
	No.		
Logging:			
Bole scar,[3] on lower one-third	49	21	10
Bole scar, on upper two-thirds	5	1	1
Bole scar, on lower one-third and upper two-thirds	23	5	11
Bole scar, on lower one-third, and less than 40 percent crown destroyed	4	1	1
Bole scar, on upper two-thirds, and less than 40 percent crown destroyed	2	1	0
Bole scar, on lower one-third and upper two-thirds, and less than 40 percent crown destroyed	5	1	3
Bole scar, on lower one-third, and more than 40 percent crown destroyed	2	0	1
Bole scar, on upper two-thirds, and more than 40 percent crown destroyed	1	0	1
Bole scar, on lower one-third and upper two-thirds, and more than 40 percent crown destroyed	3	0	3
Crown, less than 40 percent destroyed	4	2	2
Crown, more than 40 percent destroyed	1	0	1
Bent or leaning	5	18	2
Bent or leaning, with any kind of scar	2	13	0
Prostrate	29	13	21
Prostrate, with any kind of scar	15	7	13
	150	83	70
Weather:			
Snow or ice	49	35	4
Wind	0	2	0
Sunscald	3	0	0
	52	37	4
Dwarf mistletoe (*Arceuthobium* sp.):			
In bole	2	1	1
In bole and branches	3	5	0
In branches	9	9	0
	14	15	1
Disease (excluding dwarf mistletoe):			
Brown felt blight ("snow mould") (*Herpotrichia nigra* Hartig)	4	14	0
Unknown	3	0	0
	7	14	0
All others:			
Defective form (severe crook, sweep)	23	28	2
Fire	1	1	0
Animals (browsing)	0	13	0
Animals (rodents)	0	1	0
Unknown	19	3	0
	43	46	2
Total	266	195	77
Total trees affected[4]	240	167	77

[1]"Mortality" indicates only that trees of certain originally rated damage classes died, not necessarily that they died because of the specific damage or defect listed.

[2]A single tree could be observed to have more than one kind of damage.

[3]Size not specified.

[4]Number of trees may not equal number of observations because damage increased during study.

At the end of the study, milacre stocking along this transect was:

	Milacre stocking (percent)
Unstocked	24
Stocked	76
With advance reproduction only	15
With advance reproduction and new seedlings	33
With new seedlings only	28

Causes of Damage

Logging caused more damage to small trees than did any other agent *(table 1)*. Bole scars were the most frequent form of logging damage. However, many bole scars healed completely–at least externally–during the short span of this study. Some trees categorized as bent, leaning or prostrate in the final observation may have been mistallied under "logging" as the cause. Since plots were disturbed only by the original logging, some of the "final" observations in bent, leaning, or prostrate categories probably should have been listed under snow or ice damage.

"Snow or ice" was the second most damaging agent encountered. Dwarf mistletoe *(Arceuthobium* sp.*)* infections, the third most damaging agent, were relatively light throughout the study areas, and neither they nor other pathogens caused any notable mortality.

Effects of Damage on Mortality

Of the original 240 trees with damage, 77 (32 percent) died *(table 1)*. Eighteen more trees were damaged and died during the study period. Still another 22 surviving trees sustained damage after in-itial observation.

The relationship of initial damage classification to mortality of small white and red firs was affected particularly by the higher relative rate of mortality of red firs less than 1 foot tall, and more specifically, the undamaged trees in that size class *(table 2)*. Trees taller than 6 feet of any species died only if they had been damaged.

Primary Causes of Mortality

Primary and secondary causes of death of trees were recorded as "best estimate" at each annual examination. Logging damage caused only 18 percent of mortality. Effects of competition, and some instances of "shock," probably account for much mortality indicated as "other" and "unknown."

	No. of trees
Logging damage	53
Pathological (but not dwarf mistletoe)	
Insects	7
Weather	8
Other	93
Unknown	125
Total	287

Some of the records listing greater detail with "other" and "unknown" categories have been misplaced. In both classes, effects of competition and drought were either obvious or suspected in many instances. Cause of death could not be positively identified in the 44 percent of mortality assigned to the "unknown" category. In the end, record of secondary causes showed nothing significant.

Mortality with Time

Because plots were installed in different years and because no records were obtained in fall 1962, mortality during years 1 and 2 and years 4 and 5 were

Table 2–*Trees with and without initial damage, and subsequent mortality within those classes, Swain Mountain Experimental Forest, California*

Species	Trees	Initial damage class		Mortality of trees initially classed as		Total mortality
		Undamaged	Damaged	Damaged	Undamaged	
	No.	*Percent*				
Lodgepole pine	24	67	33	19	0	12
White fir	351	73	27	29	40	32
Red fir	452	69	31	41	30	38
Total	827	–	–	–	–	35

grouped. Mortality during the first 3 years after cutting made up about three-fourths of the 7-year total:

	White fir	*Red fir*
	(percent)	
Years after cutting:		
1,2	53	60
3	17	15
4,5	22	19
6	4	5
7	4	1

Growth

In 1969, I examined growth on the 1958-69 release-cut areas from which all merchantable trees had been removed. Before release most seedlings and saplings had grown only 0.1 or 0.2 foot in height per year *(fig. 6)*. In 1968 and 1969, a few of these trees with the greatest amount of growing space already were increasing their height by 0.9 to 1.1 foot per year. On the average, rate of height growth of the trees receiving most release was increased about four times. Increased height growth rate was not generally noticeable until the fifth year after release. But I have seen a stand in the Sierra Nevada where height growth response of red fir was noticeable in the third year after release. Consequently, no common release-response pattern is apparent from this study.

Diameter growth response to release was evident within 1 to 2 years for both firs. Piths were off-center in nearly all disks cut from stems at ground level. Most of these young trees had stem crooks near the ground from snow bend. After release, stems buttressed rapidly to counteract bending forces. Buttressing gives a somewhat exaggerated indication of diameter growth rate at ground level, where disks were cut. Ground level was chosen as a common height at which to determine total age and diameter growth rate, since many trees were less than 4.5 feet tall when released.

Before trees were released, their radial growth was 70 to 100 rings per inch *(fig. 6)*. After release, those having moderate to good growing space averaged 7 to 12 rings per inch. Some of the largest trees were adding ¼- to ½-inch-wide rings each year.

Tree ages at time of release ranged from 39 to 45 years. At those ages total height was only 2.2 to 5 feet, and diameter inside bark at ground level was 0.7 to 1.2 inches. The suppressive effect of larger overstory trees is obvious.

Additional observations of rapid growth rates of both white and red fir became possible when some

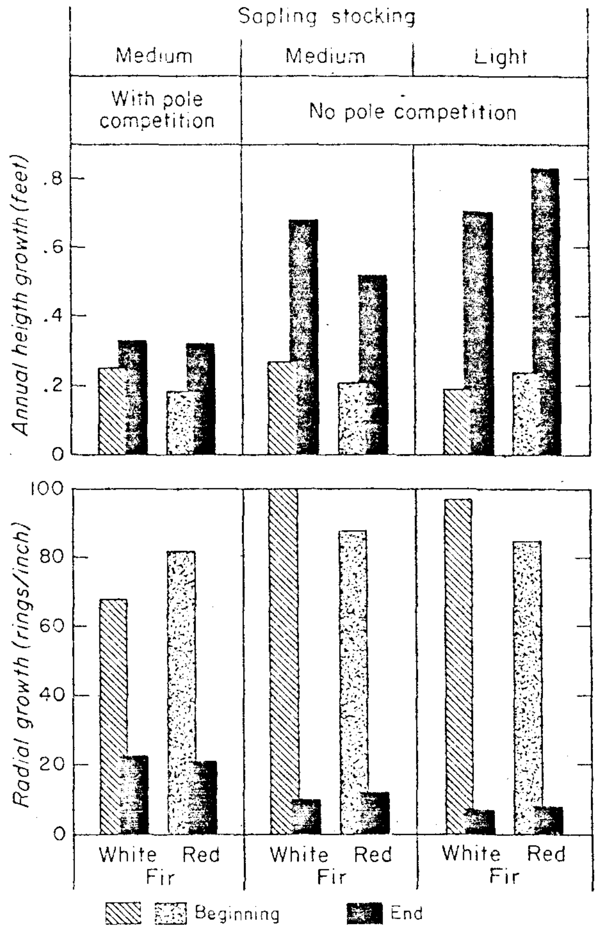


Figure 6—After overmature overstory was removed, height growth of red fir and white fir saplings increased, and the number of annual growth rings per inch decreased in a study on the Swain Mountain Experimental Forest.

young former understory trees remaining on the 195S-60 clearcut strips were cut for a special project in summer 1972. Most had been small poles (4 to 8 inches d.b.h.) when the overstory was removed. Those with most growing space had been consistently adding 3/8-inch to 1/2-inch radial growth per year at stump height. Only those which had been situated in a few relatively crowded groups were adding as little as 1/4-inch radial growth per year. Furthermore, dominant trees of post-logging red fir reproduction originating on clearcuttings in 1961 had grown by 1972 to heights of 5 to 6 feet and more. These seedlings grew slowly for the first 3 to 4 years, then began to grow more rapidly in height.

DISCUSSION

Forestry literature is replete with statements that white fir and red fir grow slowly for the first 30 years or more. What has emerged is a sort of folklore about the growth habits of these two species. Occasionally, there has been some slight modification of the statements–an allusion to several factors affecting growth other than release. One of the earliest references I know of about the effect of cutting on fir advance reproduction is found in Dunning's (1923) report, which includes a photograph titled "Heavy cutting... on Site I, effective in releasing the abundant advance growth of sugar pine and white fir ...." It illustrates lengthening internodes near the tops of fir saplings, but provides no supporting data in the text. At the time, cutting results were reported primarily as they affected mature and overmature residual trees–but not the understory.

Papers on the silvical characteristics of white and red firs by Fowells (1965), Hallin (1957), and Maul (1958) are often cited as sources. They include references to others' observations that early growth of the two species is slow. Such observations were probably made in uncut forests. And in that context, the conclusions drawn are certainly true. Maul (1958), for example, found repeated references in the literature that, in essence, claim that white fir grows “very slowly for the first 30 (or 40) years." He traced the statement as far back as the early 1900's (Kerr 1913). My point here is to refute such statements in the literature that the early growth rate of fir is, without qualification, slow.

Studies at the Swain Mountain Experimental Forest have shown that small fir trees, some of which grew slowly in an understory for more than 40 years, will develop rapidly after release from overstory. Furthermore, rapid growth rates of newly established natural regeneration in clearcuttings have been reported here. I hope that these findings will put to rest a troublesome ghost in the literature.

Behavior of white and red fir advance reproduction after release does not differ significantly from that of some other fir species. European silver fir *(Abies alba* Mill.*)* adapts itself to release in 2 years and increases height growth in the third year (Bellon and Kowalski 1968)—somewhat more rapidly than white and red fir. Hatcher (1960, 1964) found that small balsam firs *(A. balsamea* L. [Mill.]*)* increased in height growth rate within 3 years after release. Also, within a given height or age class, height growth after release was directly related to vigor at time of release.

Snow damage exceeded all other kinds of natural damage, but did not appear to create a serious obstacle to survival of adequate numbers of red and white fir seedlings and saplings. Some groups of large poles on the cutting areas had a few trees damaged by snow during the 2-year period following cutting, but these were outside measured plots. This kind of damage also has been seen in unreleased groups, so it may be a natural "thinning" process.

The effect of logging and other damage on future heart rot should be investigated. Aho (1960) found this hazard to be low in Pacific silver fir *(A. amabilis* [Dougl.) Forbes*)* reproduction in the Wind River area of Washington. I found that logging-caused bole scars on many small white and red fir trees healed externally within 7 years.

The extremely slow growth of abundant fir saplings beneath scattered old trees indicated that uneven-aged culture will be inferior to even-aged culture if rapid tree growth is desired.

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Advance reproduction of white fir and red fir released by cutting overmature overstory was studied at the Swain Mountain Experimental Forest in northern California, at 6,300 feet elevation. Seedling and sapling height growth before logging was only 0.1-0.2 foot per year. Five years after cutting, seedling and sapling height growth had accelerated to about 0.5 to 0.8 foot annually, with better trees growing 0.9-1.1 foot. Radial growth rate at ground level increased from 70 to 100 rings pet inch to 7 to 12 rings; some trees grew 2 to 4 rings. Damage to advance reproduction was caused by logging, snow or ice, and several miscellaneous agents. Mortality after cutting was attributable mostly to logging damage and to effects of competition and drought. Vigor of dominant released trees increased greatly after cutting, with milacre stocking about 50 percent.

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Advance reproduction of white fir and red fir released by cutting overmature overstory was studied at the Swain Mountain Experimental Forest in northern California, at 6,300 feet elevation. Seedling and sapling height growth before logging was only 0.1-0.2 foot per year. Five years after cutting, seedling and sapling height growth had accelerated to about 0.5 to 0.8 foot annually, with better trees growing 0.9-1.1 foot. Radial growth rate at ground level increased from 70 to 100 rings pet inch to 7 to 12 rings; some trees grew 2 to 4 rings. Damage to advance reproduction was caused by logging, snow or ice, and several miscellaneous agents. Mortality after cutting was attributable mostly to logging damage and to effects of competition and drought. Vigor of dominant released trees increased greatly after cutting, with milacre stocking about 50 percent.

Oxford: 243:231.1:181.65 + 174.7 *Abies concolor* + 174.7 *Abies magnifica*].

Retrieval Terms: Abies concolor; Abies magnifica; advance growth; liberation cutting; growth response; Swain Mountain Experimental Forest.

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