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RESULTS OF REGENERATION CUTTING IN A SPRUCE-ALPINE FIR STAND

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INTRODUCTION

Development of the Engelmann spruce (Picea engelmannii Parry)-subalpine fir (Abies lasiocarpa (Hook) Nutt.) forest in the northern Rocky Mountains has posed many problems for the forest manager. Because the forest grows at high elevations and is costly to develop, it presents many silvicultural problems, particularly in designing cutting practices and in working out the best regeneration process. A low level of utilization, until recent years, meant limited experience in spruce management. Recently, however, forest managers have begun to utilize Engelmann spruce to supplement the short supply of other quality species, and also to control insect epidemics that threaten the overmature stands.

One of the principal problems in developing the spruce type is to convert dominant old-growth stands to stands comprised of young growing stock. Harvest cutting and natural regeneration present one solution. One such cutting was attempted in northern Idaho from 1916 through 1925. Observations of this area were made in 1921, 1929, and 1954; this paper reports the establishment and development of regeneration and changes in the residual stand.

STUDY AREA

The study area is located in Spruce Creek on the Kaniksu National Forest in northern Idaho at an elevation ranging from about 4,200 to 6,000 feet. The stand varied from a white pine type on the slopes at the lower end to a pure spruce-fir stand on the upper slopes and in the basin at the head of the stream (fig. 1). The stand on the slopes was composed of a mixture of species with a predominance of Engelmann spruce but with white pine in the mixture where the white pine and Engelmann spruce-subalpine fir types merged. The basin supported a nearly pure spruce-subalpine fir stand. Age of the residual trees ranged from 118 to 140 years. The whole area can be classified as a Picea-abies/menziesia ecological habitat type.[1]

Logging started in the summer of 1916 and was completed by the end of 1925. Area logged each year varied from a high of 133 acres in 1917 to a low of 43 acres in 1918. Area cut in the other years ranged between these extremes, and a total of about 800 acres was cut over. The total yield amounted to approximately 23.5 million board feet. The volume removed was comprised of 56 percent spruce, 31 percent subalpine fir, 5 percent western white pine, and 8 percent mixed western larch, Douglas-fir, and lodgepole pine.

Except for a tract of 30 acres, the total area was clearcut, leaving seed-tree groups, strips, and blocks. On the clearcut area, seed-tree groups were composed of 15 to 20 trees each; strips were 1 chain wide and of different lengths; and two blocks were of 1-acre size. The 30-acre tract was partially cut, reserving 27 percent of the original volume. Locations of the partial cutting, seed-tree groups, strips, and blocks are shown in figure 1.

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[1] Daubenmire, R. Forest vegetation in northern Idaho and adjacent Washington and its bearing on concepts of vegetation classification. Ecol. Monog. 22: 301-330, illus. 1952.

Figure 1.--Study area.

STUDY METHODS

Partial cutting.--Volume and growth of the residual trees in the partial cutting were measured in 1954 by means of temporary sample plots at 14 randomly selected locations. At each location data were collected on three different-sized concentric plots as follows:

1. Residual trees 9.6 inches d.b.h. and larger were recorded on a 1/5-acre circular plot, and trees 3.6 inches to 9.5 inches d.b.h. were recorded on a 1/10-acre plot. Diameter at breast height, total and merchantable height, dominance, external traits of vigor, defect, growth by 5-year periods before and after logging (from increment cores), and mortality since logging were determined and recorded for each tree.

2. The reproduction (trees to 3.5 inches d.b.h.) was tallied by height and diameter on a 4-milacre circular sample plot.

Clearcutting.--Reproduction counts on the group seed-tree cuttings were made in 1954 on randomly located sampling units. Each sampling unit was five 4-milacre circular sample plots spaced 1 chain apart along a 5-chain segment of a line (fig. 1). On each plot, species were recorded by height and diameter classes. Earlier reproduction counts had been made on milacre plots[2] in 1921 on the lower portion of the area, and in 1929[3] counts were made over all of the area except the 30-acre partial cutting.

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[2] Lowdermilk, W. C. The management of Engelmann spruce--the basis for marking and slash disposal rules. U.S. Forest Service. Unpublished typewritten report. 40 pp. 1922.

[3] DeJarnette, G. M. Report on cut-over area examination. U.S. Forest Service. Unpublished typewritten report. 18 pp. 1931.

ANALYSIS OF THE DATA AND RESULTS

RESIDUAL STAND GROWTH

In addition to providing a large controlled seed source and shade protection for the site, partial cutting makes available high-quality, selected growing stock. Because part of the trees are removed by logging, the success of the growing stock hinges to a large degree upon the ability of the residual trees to accelerate and maintain good growth rates and to remain windfirm. The following analysis evaluates the growing stock in the partial cutting on the basis of these criteria.

Gross and net growth.--The original stand volume on the partial cutting averaged about 29,000 board feet Scribner per acre; about 7,000 feet per acre, chiefly Engelmann spruce, remained in the residual stand in 1924. Subalpine fir was the principal associate, and only minor quantities of other species were present.

In partial cuttings, foresters aim to leave trees that can respond to release and make good growth. The Engelmann spruce residual made a good net gain of 3,035 board feet per acre in the 30-year period 1924-1954, but the subalpine fir sustained a net loss of 62 board feet (table 1). Deductions for defect were not made from the volumes in table 1 because a quantitative value for this factor was not available for the residual stand in 1924. However, defect as determined by increment borings in 1954 was 6 percent of the volume in Engelmann spruce and 48 percent of the subalpine fir. Heart rot was chiefly responsible for the defect. The large volume of defect in subalpine fir further accentuates the difference in the growth between the two species shown in the table.

Table 1.--Thirty-year gross and net growth and mortality [1]

Species	Residual volume in 1924	Volume in 1954	30-year growth		Periodic annual growth		Annual mortality
			Net	Gross	Net	Gross	
	Board feet						
Engelmann spruce	5,906	8,941	3,035	4,255	101	142	41
Subalpine fir	1,082	1,020	–62	729	–2	24	26

[1] Values rounded to the nearest board foot; no deductions made for defect.

Although Engelmann spruce usually is not windfirm, mortality in the residual stand in this study was not unduly high. This may have been because the stand was situated below the crest of a ridge in a reasonably well-protected location. The annual mortality of 41 board feet per acre of Engelmann spruce was caused primarily by windthrow, while much of the mortality in subalpine fir appeared to be caused by sunscalding and insects. The following tabulation shows the estimated percent volume loss by cause for both species.

Cause of loss	Engelmann spruce	Subalpine fir
Windthrow	81	11
Windbroken	4	--
Root rot and windthrow	7	--
Insects	8	19
Sunscalding	--	56
Unknown	--	14

Response of residual trees in relation to time.--One of the chief reasons for reserving trees on a cutover area, besides providing a seed source, is to obtain additional growth on quality trees. This concept implies that the remaining trees will increase their increment when the stand is thinned by cutting. The residual trees responded significantly to logging release with acceleration in diameter growth, beginning in the second 5-year period after logging (fig. 2). The diameter increment remained high through the 6- to 30-year period after logging but fell off slightly during the last 5-year period. DeJarnette[4] reported no evident increase in diameter growth after an examination of the cutting in 1929; this confirms the lack of response depicted in the first 5-year period in the 1954 data.

Changing climatic conditions as well as release by logging can bring about accelerated diameter growth rates in trees. To help eliminate the effect of climatic factors and isolate the effect of logging release in the analysis, growth rates in an adjacent uncut stand were compared with those in the cutover residual stand. The trees in the cutover stand grew considerably more than those in the uncut stand; and the substantial difference between the two represents the response attributable to release.

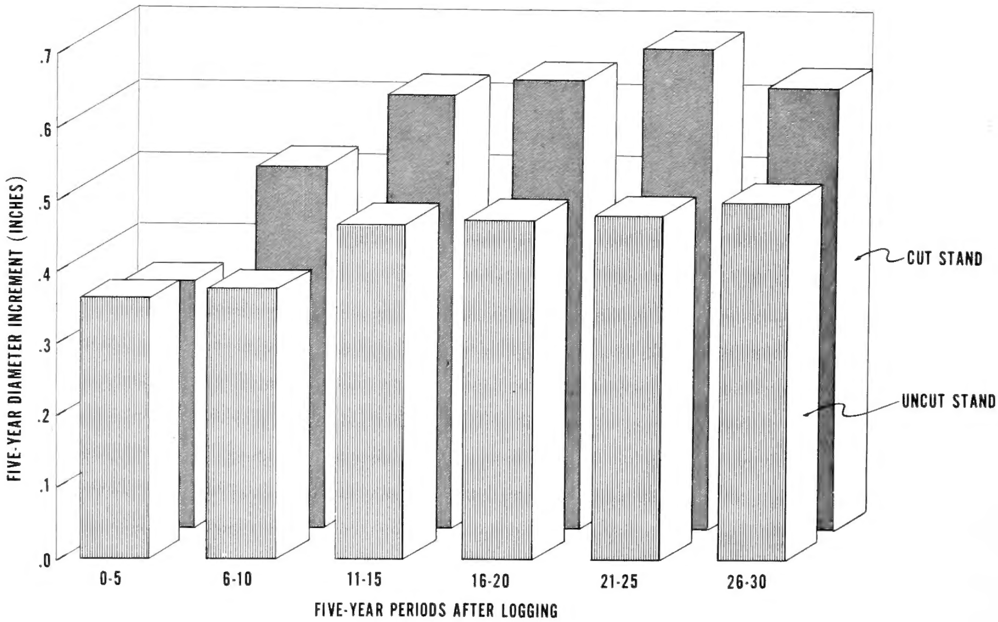

Figure 2.--Average diameter increment of trees in relation to time since cutting.

[4] Ibid.

Response of residual trees in relation to tree size.--Stand structure and size and vigor of trees influence stand growth. In this study, growth response was related to initial tree size. Table 2 shows that an Engelmann spruce tree 8.1 inches d.b.h. at logging reached 10 inches d.b.h.--a 1.9-inch increase in diameter--in 30 years. On the other hand, a 20.6-inch tree at time of logging grew to 25 inches in 30 years--a 4.4-inch diameter increase. Thus a preponderance of large trees in the residual stands helps to develop good stand growth. The same relationship is shown for subalpine fir in table 3.

Response of residual trees in relation to tree vigor.--A preponderance of good and fair vigor trees also influenced the diameter growth of the residual trees (table 4). More than two-thirds of the spruce trees in the cutover stand showed fair to good vigor. Differences between mean growth for vigor classes were significant at the 1-percent level. Further, a covariance analysis showed that the regression coefficients of 5-year diameter increment on crown length were significantly different among dominance classes. Vigor classes used in the field were based upon a vigor classification developed previously for western larch and Douglas-fir trees.[5] Since bark characteristics shown in the classification did not apply, they were not used; however, all other criteria were applied and proved useful in classifying the Engelmann spruce and subalpine fir trees.

Table 2.--Diameter breast high outside bark of Engelmann spruce trees 30 years before logging and at 5-year intervals after logging[1]

30 years before logging	Years after logging						
	0	5	10	15	20	25	30[2]
	Inches						
7.4	8.1	8.2	8.4	9.0	9.4	9.6	10
8.1	8.9	9.0	9.3	9.9	10.3	10.5	11
8.7	9.8	9.9	10.2	10.8	11.2	11.5	12
9.3	10.6	10.7	11.1	11.7	12.2	12.5	13
10.0	11.4	11.6	12.0	12.6	13.1	13.5	14
10.6	12.3	12.5	12.9	13.5	14.0	14.4	15
11.3	13.1	13.3	13.8	14.4	14.9	15.4	16
11.9	13.9	14.2	14.6	15.3	15.9	16.4	17
12.6	14.8	15.0	15.5	16.2	16.8	17.4	18
13.2	15.6	15.9	16.4	17.0	17.7	18.3	19
13.8	16.4	16.8	17.3	17.9	18.6	19.3	20
14.5	17.3	17.6	18.2	18.8	19.5	20.3	21
15.1	18.1	18.5	19.1	19.7	20.4	21.3	22
15.8	18.9	19.3	20.0	20.6	21.4	22.2	23
16.4	19.8	20.2	20.8	21.5	22.3	23.3	24
17.1	20.6	21.0	21.7	22.4	23.2	24.2	25
17.7	21.4	21.9	22.6	23.3	24.1	25.2	26
18.4	22.2	22.7	23.5	24.2	25.0	26.1	27

(See footnotes at end of table, page 6)

[5] Roe, Arthur L. A preliminary classification of tree vigor for western larch and Douglas-fir trees in western Montana. U.S. Forest Serv., North. Rocky Mountain Forest & Range Expt. Sta. Res. Note 66, 6 pp., illus. 1948.

Table 2.--(con.)

30 years before logging	Years after logging						
	0	5	10	15	20	25	30[2]
	Inches						
19.0	23.1	23.6	24.4	25.1	25.9	27.1	28
19.7	23.9	24.5	25.3	25.9	26.8	28.0	29
20.3	24.7	25.3	26.2	26.8	27.8	29.0	30

[1] This table was derived from regression equations based on the following constants:

Years after logging	b coefficient	a constant	r^2
0	0.833	−0.209	0.876
5	0.859	−0.441	0.899
10	0.888	−0.467	0.929
15	0.890	+0.149	0.961
20	0.919	+0.221	0.950
25	0.975	−0.159	0.996
30 years before logging	0.645	+0.971	0.681

[2] Diameter class at year of measurement (1954) is also the independent variable in the regression equation.

Table 3.--Diameter breast high outside bark of subalpine fir trees at 5-year intervals after logging[1]

Years after logging						
0	5	10	15	20	25	30
Inches						
8.0	8.2	8.4	8.6	8.8	9.3	10.0
8.6	8.9	9.2	9.6	9.8	10.4	11.0
9.3	9.7	10.1	10.5	10.8	11.4	12.0
10.0	10.4	10.9	11.4	11.9	12.4	13.0
10.7	11.2	11.7	12.3	12.9	13.5	14.0
11.4	11.9	12.5	13.2	13.9	14.5	15.0
12.1	12.6	13.3	14.1	14.9	15.5	16.0
12.8	13.3	14.1	15.0	16.0	16.6	17.0

[1] This table was derived from regression equations based on the following constants:

Years after logging	b coefficient	a constant	r^2
0	0.685	+1.125	0.810
5	0.736	+0.824	0.854
10	0.811	+0.329	0.933
15	0.903	+0.375	0.970
20	1.026	−1.451	0.980
25	1.026	−0.915	0.992

[2] Diameter class at year of measurement (1954) is also the independent variable in the regression equation.

Table 4.--Five-year diameter growth breast high and average crown length by vigor and crown class

Crown class	Good vigor		Fair vigor		Poor vigor	
	Average crown length	Average increment	Average crown length	Average increment	Average crown length	Average increment
	Percent	Inches	Percent	Inches	Percent	Inches
Dominant and codominant	68.5	0.827	61.1	0.666	55.7	0.468
Intermediate and suppressed	--	--	51.2	.482	34.0	.345

Gross volume increment in relation to time.--Because volume of trees is dependent upon diameter and height, it is expected that volume increment will respond to treatment the same as diameter growth has. As shown in table 5, 5-year periodic annual volume increment increased substantially in the second 5-year period (6 to 10 years after logging). The periodic annual increment continued to increase in all but the last 5-year period, when it began to fall off slightly. The study shows that in partial stands of this kind, residual spruce can be expected to accelerate its increment and continue to grow well for 25 to 30 years after logging.

Table 5.--Gross volume increment per acre of surviving residual trees and ingrowth

Species and tree class	Periodic annual increment						Total 30-year increment	P.A.I. 30-year period
	Years after logging							
	0-5	6-10	11-15	16-20	21-25	26-30		
	Board feet							
Engelmann spruce:								
Residual [1]	64.6	113.0	133.0	158.2	190.2	189.0	4,240	141.3
Ingrowth [2]	--	--	--	--	2.8	.2	15	.5
Total	64.6	113.0	133.0	158.2	193.0	189.2	4,255	141.8
Subalpine fir:								
Residual	7.6	10.4	15.2	18.4	16.2	13.4	406	13.5
Ingrowth	--	5.6	14.0	2.0	3.2	39.8	323	10.8
Total	7.6	16.0	29.2	20.4	19.4	53.2	729	24.3

[1] Trees 9.6 inches d.b.h. and larger at time of logging.
[2] Trees reaching 9.6 inches d.b.h. and larger size after logging.

Ingrowth.--Another important source of volume increment in partially cut stands is contained in trees smaller than merchantable size (9.6 inches d.b.h.) at logging that subsequently grow into merchantable size. These trees are not measured in board-foot volume until they reach the 10-inch d.b.h. class. Ingrowth contributed very little volume increase for Engelmann spruce, but comprised nearly half of the gross volume increment for subalpine fir. Ingrowth of Engelmann spruce did not appear until the 21- to 25-year period after logging, but the ingrowth of subalpine fir became part of the merchantable stand within 6 to 10 years after logging and continued to increase over the period. The subalpine fir, although small, were old and had approached or passed their peak vigor.

STATUS AND PROGRESS OF NATURAL REPRODUCTION

The primary objective of regeneration cutting is to establish a new stand by natural regeneration. This entails providing an adequate seed source, an effective seedbed, and other site and climatic conditions favorable to seedling establishment. In discussion of natural regeneration the area will be referred to in three units, namely: (1) partial cutting, (2) clearcut basin unit, and (3) clearcut slope unit (fig. 1).

Seed source.--A seed source may be provided by leaving scattered seed trees, shelterwood in partial cuttings, or uncut timber margins surrounding clearcut blocks, strips, or patches. In this study a shelterwood remained in the partial cutting. The seed source in the clearcuttings was contained in groups of 15 to 20 seed trees, 1-chain-wide strips, and two 1-acre blocks of seed trees. In 1929, about 5 years after the last cutting, DeJarnette[6] carefully examined the condition of the seed source. He reported very heavy mortality, largely windfall, of mature trees in the strips and seed-tree groups. Of the total number of seed-tree groups left, only 38 percent retained one or more live trees. Out of 30 groups which were identified and examined in detail, about half had one-fourth or fewer of original trees surviving, one-third of the groups had between one-fourth and one-half of the trees surviving, and only one-sixth of them had as many as one-half or more of the original number surviving. DeJarnette also reported similar results in the strips. By 1954 it was practically impossible to identify any of the seed-tree groups or the strips. However, enough surviving trees were present to identify the two 1-acre blocks.

Analysis of the 1954 data shows evidence of seeding in the clearcut units from the surrounding uncut timber. The mean number of trees per acre in reproduction 2.6 feet and taller was 369, based upon plots that fell within 10 chains of the timber edge--as compared with only 250 trees per acre beyond 10 chains from the timber edges. The difference of 119 trees was significant at the 5-percent level in "t" tests. Because of the early loss of much of the seed source left within the clearcut areas after logging, it is doubtful whether that source contributed much seed for reproduction.

Seedbed.--Differences among seedbeds after 30 years could not be readily distinguished in 1954. Some skidroads and soil bared by upturned roots were still discernible. Skidroads could be identified by the reproduction on them and impressions in the ground. However, most of the areas disturbed by the logging operations had been completely clothed by trees and other vegetation, particularly *Menziesia ferruginea*, commonly known as buckbrush, which is the predominant shrub now.

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[6] Op. cit.

In 1921, Lowdermilk[7] examined a portion of the area that had been cut in 1916 and 1917; slash had been piled and burned in 1918. He reported the following condition of the seedbed:

	Percent
Burned seedbed (burning of slash piles, etc.)	13.1
Mineral soil (exposed by mechanical disturbance)	13.3
Natural undisturbed forest floor	73.6
	100.0

Although these values represent only the lower slopes, they nevertheless indicate the proportions of mineral soil and burned seedbed that were exposed by the logging and slash disposal operations. No additional seedbed was prepared. It seems safe to assume that these figures may apply reasonably well to the whole area.

The superiority of mineral soil seedbed as opposed to undisturbed natural forest floor was established by Lowdermilk's studies in 1921. The following tabulation compares the percentages of stocked milacre plots by surface conditions as he found them:

Seedbed	Engelmann spruce	Subalpine fir and other
Burned surface	20.4	30.6
Mineral soil	95.0	100.0
Natural forest floor	9.0	9.0

Lowdermilk pointed out that the stocking on burned areas was disappointing. He theorized that the hot fires caused by burning piles sterilized the soil; such sterilization may explain why the centers of the burned spots did not stock satisfactorily. Even so, the burned surface was two or three times better stocked than the natural forest floor. The number of trees per acre shows a similar trend, as illustrated by the following tabulation:

Seedbed	Engelmann spruce	Subalpine fir and other
Burned surface	405	356
Mineral soil	2,300	1,405
Natural forest floor	109	118

Although Lowdermilk's observations were limited to cutting before 1919, comments in reports of later examinations bear out the same trends in other parts of the area.

Stocking of reproduction.--In both 1929 (DeJarnette)[8] and 1954, a fair stocking of Engelmann spruce and subalpine fir on the clearcut areas was found despite the heavy loss of seed source shortly after logging and the limited amount of favorable seedbed (table 6). These examinations dealt with three units based upon physiography and method of cutting, and made no attempt to recognize seedbed condition that was no longer discernible or to distinguish between the kinds of the seed source (i.e., 15 to 20 tree groups or strips) in the clearcutting.

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[7] Op. cit.

[8] Op. cit.

Table 6.--Four-milacre plots stocked with one or more seedlings

Year	Partial cutting		Clearcutting with seed-tree groups			
			Basin unit		Slope unit	
	Engelmann spruce	Subalpine fir	Engelmann spruce	Subalpine fir	Engelmann spruce	Subalpine fir
	- - - -	- - - -	- - - -	Percent	- - - -	- - - -
1954	[1] 64(43)	43(29)	58(34)	84(48)	56(48)	52(52)
1929	--([2])	--([2])	35	39	60	71

[1] Numerals in parentheses include only trees 2.6 feet and taller that were considered well established and able to compete with other vegetation.

[2] Reproduction counts in the partial cutting area were not made in 1929.

However, stocking by well-established reproduction in the clearcut area in 1954 did not increase substantially after the 1929 examination (table 6). The increase in stocked quadrats in the 1954 figures may be attributed to 1-year-old seedlings and to older seedlings so badly suppressed by other vegetation that their survival is doubtful. Many 1-year seedlings start even under very heavy shrub cover, but very few survive long enough to become established trees. After careful examination of the 1954 stand, only those seedlings that had reached the 3-foot height class were judged to have a fair probability of becoming a part of the productive stand within a reasonable period of time. On the basis of seedlings 2.6 feet or taller, it appears that the well-established seedlings are mainly those that were established by 1929; and accretion in numbers of new seedlings very nearly balanced losses. On the slope unit, the stocking in 1929 considerably exceeded that of the basin unit, but by 1954 the difference in stocking on the two areas was much less. The means of both total number of seedlings and seedlings 2.6 feet and taller on the slope and basin units were not significantly different in 1954 as revealed by "t" tests.

Composition of the reproduction stand.--The highest ratio of spruce to subalpine fir occurred in the reproduction established under the partial cutting. This is best illustrated in table 7, which shows more than $1\frac{1}{2}$ times as many spruce as subalpine fir trees. This favorable ratio may be attributed to the greater number of spruce than subalpine fir seed trees in the residual stand of the partial cutting. On the other hand, in the clearcuttings the subalpine fir outnumber spruce in the reproduction by about four to one. The greater incidence of spruce seedlings in the partial cutting reflects the better seed control achieved by the partial cutting.

Table 7.--Composition of reproduction by cutting areas and species

Area	Engelmann spruce	Subalpine fir
	- - - Trees per acre	- - -
Clearcut basin	580	2,190
Clearcut slope	450	1,980
Partial cutting	838	519

Development of the seedling stand.--Although a larger proportion of spruce to subalpine fir seedlings was established in the partial cutting, the best growth and development of seedlings after they were established occurred in the clearcutting. None of the spruce seedlings in the partial cutting had attained a measurable diameter at breast height in 1954, but in the clearcutting the spruce seedlings attained mean diameters of 1.56 and 1.93 inches in the basin and slope units, respectively. Subalpine fir, on the other hand, attained mean diameters at breast height of 1.50, 1.59, and 2.22 inches in partial cutting, basin, and slope units, respectively. Height growth is also much better in spruce seedlings in the clearcuttings than in the partial cutting (see table 8). The tallest spruce seedlings in the partial cutting fell in the 5-foot height class, while 30 percent of the seedlings in the basin unit and 50 percent of those in the slope unit exceeded the 5-foot height class. Subalpine fir height growth, in contrast to the spruce development pattern, was much better in the partial cutting, where 38 percent of the seedlings were taller than the 5-foot height class, and only 6 and 10 percent of the seedlings exceeded the 5-foot height in basin and slope units, respectively. This relationship indicates that despite the protected conditions and preponderance of spruce seed source that favor seedling establishment in the partial cut, the best environment for later growth was in the clearcut areas.

Table 8.--Distribution of reproduction by total height classes

Height class (feet)	Engelmann spruce			Alpine fir		
	Clearcutting		Partial cutting	Clearcutting		Partial cutting
	Basin unit	Slope unit		Basin unit	Slope unit	
	Percent					
1	34	22	43	82	77	50
2	10	7	26	6	10	7
3	7	7	15	3	2	3
4	8	9	8	1	1	0
5	7	6	8	2	1	3
6	12	6	0	1	2	17
7	3	2	0	1	2	0
8	6	4	0	1	1	3
9	1	4	0	0	0	3
10	9	18	0	2	2	11
20	2	10	0	1	2	3
30	1	5	0	0	1	0
Total	100	100	100	100	100	100

DISCUSSION

Partial cutting is useful in Engelmann spruce management as a reproduction method. Although the partially cut stand observed in this study is small, it shows both advantages and disadvantages of the method.

On the credit side, both spruce and subalpine fir responded well to release even at the advanced ages represented by the trees in this study. The spruce residual increased its gross volume at a 2.4 percent per annum rate for 30 years. These residual trees during the regeneration period not only furnished an adequate, well-distributed seed source, but also provided natural shade to aid seedling survival in the early years and good protection for the site. At the same time, the residual trees returned a substantial increment. As illustrated in the results, the selection of good, vigorous spruce seed trees provided good control of the species composition in the reproduction.

On the debit side, however, the spruce residual presents the problem of risk from loss by windthrow. Windthrow is not an insurmountable problem because, under proper conditions of exposure, skillful cutting, and deep soil, spruce residuals can produce good net gains, as shown by this study. Studies on the east side of the Canadian Rockies[9] have shown that the blow-down problem can be alleviated by light selection cutting where reasonable reserve stands of 3,000 board feet or more per acre have been left. Further, these partially cut stands make possible another cut on the area in 30 to 40 years.

Subalpine fir, despite its good growth response to release by logging, is highly sensitive to damage and mortality from sunscalding and insect attack, and suffers a high incidence of heart rot. These facts make subalpine fir an extremely high risk in the residual stand unless the trees are very young and vigorous.

Suppression of the spruce reproduction by the residual stand, which is held for many years beyond seedling establishment, constitutes another disadvantage of partial cutting. Diameter and height growth of well-established spruce seedlings were retarded when compared with seedling growth and development in the clearcutting. The extent to which the suppressed reproduction may respond and fill the gap of lost increment when the old stand is removed is not known.

A further disadvantage of partial cutting is found in the difficulty of preparing seedbeds under the residual trees. Mechanical scarification around the bases of spruce trees very often damages roots close to the surface and, consequently, decreases vigor and increases the risk of windthrow. Prescribed burning also often damages the shallow roots of spruce and sometimes causes death by damaging the cambium. The extent to which scarification and prescribed burning may be modified to reduce their damaging effects is not known, but further investigation is highly desirable.

On the basis of this study and present experience, clearcutting with seed-tree groups, strips, or small blocks is not recommended. Seed sources of this kind are highly vulnerable to wind damage. The transitory nature of the seed sources is a serious disadvantage not only

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[9] DeGrace, L. A. Management of spruce on the east slopes of the Canadian Rockies. Canada Dept. of Resources and Development. Forest Res. Div. Silv. Res. Note 97, 55 pp. 1950.

because the volume contained in the trees is lost early through windthrow, but also because the trees may not remain upright long enough to produce useful quantities of seed. Further, such seed sources offer only a minimum opportunity to control species composition. The groups possess the same composition, usually, as the harvested stand.

Clearcutting in blocks or strips with seeding from the side or uncut timber edge is now widely practiced as a reproduction method. It was not included as a method in the cuttings described; yet, the early loss of the seed-tree groups and a fair degree of stocking throughout the clearcut area suggest that side seeding helped effect successful regeneration. Evidence in the study shows that side seeding was a significant factor within 10 chains of the timber edge.

The type of reproduction cutting to use in harvesting spruce stands should be selected carefully and the advantages and disadvantages of each method must be considered. Blind faith in any single method is not justified, but careful consideration of the site conditions and requirements will help the forest manager to select. Partial cutting under some conditions and clearcutting under others are both useful methods.

RECOMMENDATIONS

A few simple guidelines for spruce cutting are enumerated below:

Partial cutting

1. Partial cutting should be practiced only on deep, well-drained soils, away from crests of ridges or other locations in the paths of high winds. Moist, poorly drained areas are a poor risk for partial cuttings and consequently should be clearcut.

2. Trees of good vigor should be left. Select only trees in the upper dominance classes--preferably trees having long, medium-to-wide crowns.

3. A uniform canopy should be left with as little variation as possible in tree height. Making large holes in the canopy should be avoided whenever possible.

4. Subalpine fir should be removed unless the trees are very young and have long crowns. Trees with a history of long, early suppression should be avoided in the residual because of the high incidence of heart rot, and also because of their sensitivity to sunscalding.

5. Seedbed preparation that exposes mineral soil and removes competitive vegetation is required for early seedling establishment and growth.

Clearcutting

1. Clearcut blocks or strip cutting should be practiced especially in areas having moist soils or in sites that lie in the paths of high winds.

2. While block or clearcut strips can be expected to receive seed from the side (timber edge), side seeding should not be depended upon beyond 10 chains from the timber edge. The size and shape of the opening should be planned to provide standing timber within 10 chains of any part of the cutover area.

3. Planting or seeding should be planned as a supplemental measure on those areas beyond 10 chains from the timber wall. Small groups or islands of seed trees within the cutover area are not recommended.

4. Seedbed should be prepared either by mechanical scarification or broadcast burn. A cool, moist microenvironment is required for successful seedling establishment on the seedbed and can be accomplished by leaving sufficient scattered material, such as logs and branches, to provide shade and protection.

FOREST SERVICE CREED

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Roe, A. L., and G. M. DeJarnette.
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This paper discusses and analyzes effects of a harvest cutting (1916-1925) in an Engelmann spruce-subalpine fir stand in northern Idaho that left residual trees 118-140 years old. It compares the reproduction and response to release of both species under both partial and clearcutting, and it reports and analyzes advantages and disadvantages of both types of cuts in both species. Recommended guidelines can help the forest manager decide whether to clearcut or partially cut individual spruce-fir stands.

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Headquarters for the Intermountain Forest and Range Experiment Station are in Ogden, Utah. Project headquarters are also at:

- Boise, Idaho
- Bozeman, Montana (in cooperation with Montana State University)
- Logan, Utah (in cooperation with Utah State University)
- Missoula, Montana (in cooperation with University of Montana)
- Moscow, Idaho (in cooperation with the University of Idaho)
- Provo, Utah (in cooperation with Brigham Young University)

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