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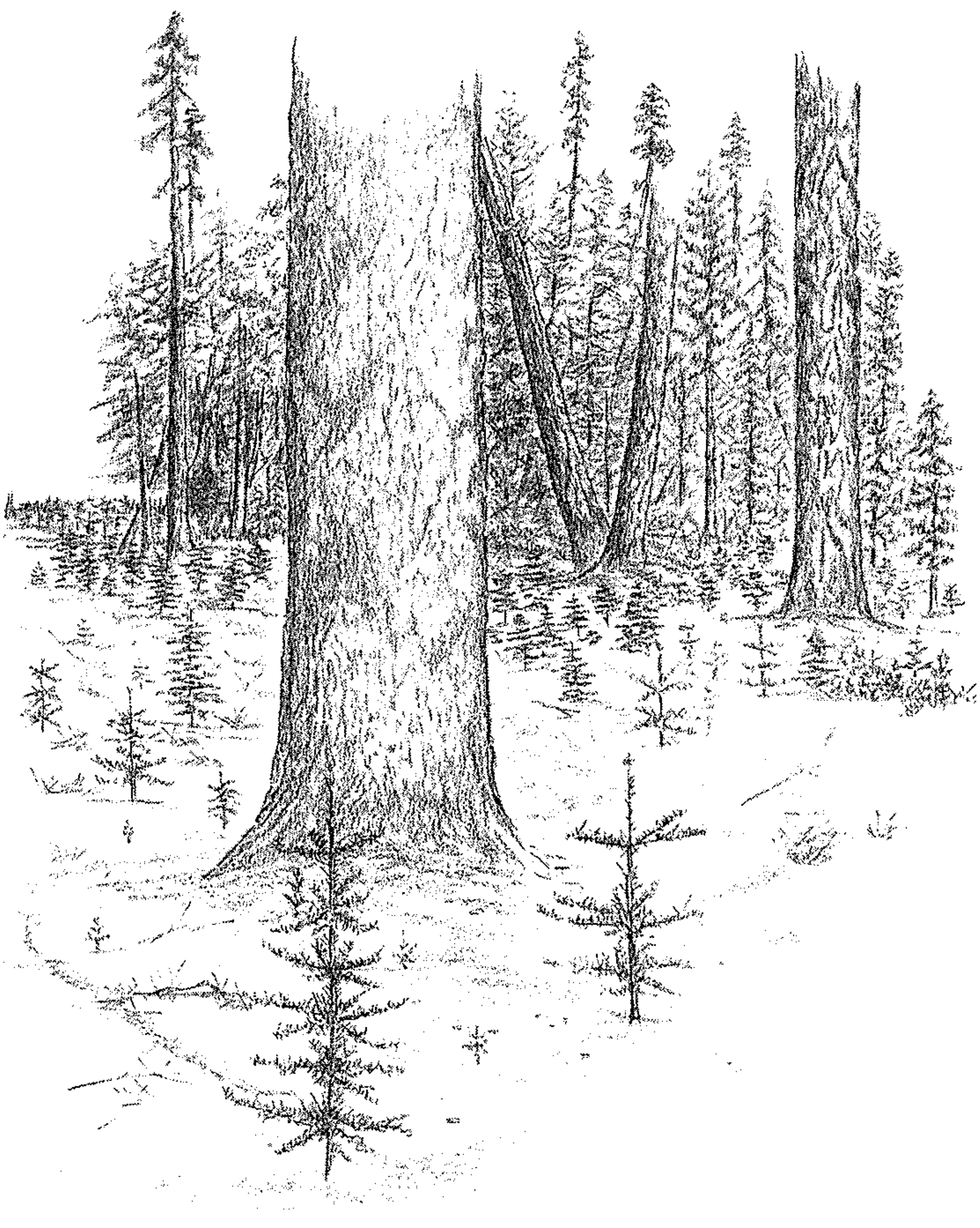
Shelterwood Regeneration of True Fir: conclusions after 8 years

Robert J. Laacke Jeanne H. Tomascheski



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IN BRIEF . . .

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Natural regeneration of true fir forests has been the focus of research at Swain Mountain Experimental Forest, in northeastern California, since 1958. One study, using small shelterwood blocks, was started in 1970 and 3-year results were published in 1979. Those results have been extended through 1978 providing several useful findings: adequate regeneration can be attained and maintained at 25 trees per ha (10/acre); density of seed trees may affect seedling growth only after the fourth year; regeneration is predominantly red fir, even where the major seed source is white fir; if appropriate tree selection criteria are used, loss of seed trees from blowdown is minimized; total seedlings produced each year were apparently not related to cone production in nearby stands.

INTRODUCTION

Natural regeneration has some significant short-term disadvantages, including lack of stocking control and uncertainty of timing. Therefore, planting has become the dominant method of regeneration in California and elsewhere. However, natural regeneration is clearly an option if the planning, economic, or legal disadvantages (arising from uncertain timing) can be resolved.

Natural regeneration of true fir forests has been the focus of research at Swain Mountain Experimental Forest, in northeastern California, since 1958. Beginning in 1970, 46.54 ha (115 acres) of shelterwood cuttings were set up into 32 squares, each 1.46 ha (3.6 acres). Three levels of shelterwood density were tested—25, 50, and 75 trees per ha (10, 20, 30/acre). Cutting was accomplished over a 3-year period and results up to 1975 have been reported (Gordon 1979).

This paper reports a study analyzing regeneration—present in 1978—to answer three questions:

- Does density of shelterwood affect seedling density up to 8 years after cutting?
- Does density of shelterwood affect seedling growth rate up to 8 years after cutting?
- When did the surviving (in 1978) seedlings originate?

STUDY AREA

Swain Mountain Experimental Forest covers 2427 ha (5998 acres) and occupies essentially all of Swain Mountain, an asymmetric volcanic cone with a steep southern face, covered by an old brush field planted to Jeffrey pine, and long, gentle slopes covered by old-growth true fir forests on the other exposures. Elevations range from 1740 to 2130 meters (5700 to 7000 ft). Precipitation averages 102 to 127 cm (40 to 50 in) per year, primarily as snow. Site quality is good (45 meters [150 ft] tall at 300 years), generally equivalent to a Dunning Class II (Dunning 1942). White fir (*Abies concolor* [Gord. & Glend.] Lindl.) and California red fir (*A. magnifica* A. Murr.) are the major tree species, with lodgepole pine (*Pinus contorta* Dougl. ex Loud.) concentrated around meadows and at lower elevations. Also present are scattered specimens of Jeffrey pine (*P. jeffreyi* Grev. & Balf.), western white pine (*P. monticola* Dougl. ex D. Don), sugar pine (*P. lambertiana* Dougl.), and incense-cedar (*Libocedrus decurrens* Torr.). The two fir species can be found in varying proportions throughout the Experimental Forest—with white fir strongly favored at lower elevations, and red fir favored at higher elevations. The cuttings were distributed in elevation between 1770 and 2070 meters (5800 and 6800 ft), with the majority between 1830 and 1920 meters (6000 and 6300 ft).

METHODS

Of the original 32 shelterwood areas, 30 were set up as 10 sets of 3 cutting areas, each set containing one replication of each treatment level. Members of each set were located adjacent to each other, separated by 40 meters (132 ft) of uncut timber. Each set was located so as to avoid environmental differences, a task made easier by the gentle slopes. All areas were originally closed stands of old-growth fir and most had little or no vegetation beneath them. There was no attempt to control competing vegetation or rodent populations following site preparation. Brush and grass cover, largely whitethorn *(Ceanothus cordulatus)* and currant (*Ribes* sp.), developed slowly and are abundant but have resulted in only scattered mortality.

Trees left as shelterwood averaged between 102 and 107 cm (40 to 42 in) in diameter at breast height (d.b.h.). After logging, only 27 areas were usable for the original study (Gordon 1973). Thirty plots, 0.0004 ha (0.001 acre) in area, were randomly located in the central 0.16 ha (0.4 acre) of each cutting area to avoid the influence of seed from adjacent, uncut stands. Each plot was permanently marked with painted steel pins. It was from a sample of these plots on selected sets that Gordon collected his regeneration data.

In 1978, all plots on each cutting area on 8 sets (a total of 24 areas) were relocated. One-third of these (10 on each area) were randomly chosen for measurement. Seedlings were counted and the following data recorded for each:

- Species, based on needle characteristics (Franklin 1961)
- Height to nearest centimeter
- Browse damage
- Age, counting terminal bud scars from the root collar up. Age of trees with browse damage was estimated using undamaged laterals. No shelterwood trees had been removed and very few had died or blown down.

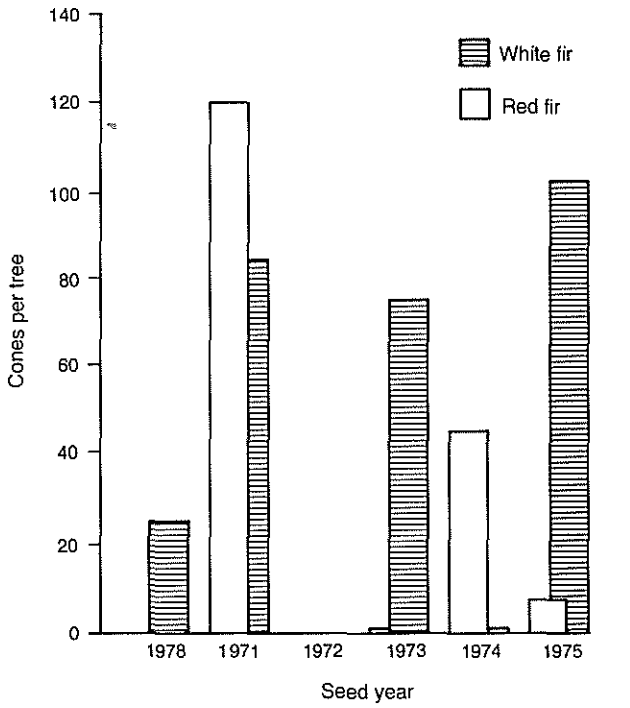

Figure 1—The average number of cones per tree on transects in uncut stands for the first 6 years after shelterwood cutting (Gordon 1978).

ANALYSES

The effect of shelterwood density on seedling density and height was analyzed using a three-factor analysis of variance: treatment and year as fixed effects and blocks as a random effect nested in year. Seedling height was analyzed using a four-factor analysis of variance: age, treatment, and year as fixed effects and blocks as a random effect nested in year.

Only one usable set of three levels was logged in 1972. Since no statistical comparisons could be drawn within that year, analyses were limited to areas logged in 1970 and 1971 (a total of 8 sets, 4 each year). Where the analysis of variance indicated a difference (reject the hypothesis of no difference), the Tukey test was applied to the means. Significance levels were set at 5 percent for analysis of variance and Tukey tests.

RESULTS

There were 2776 seedlings present on 240 plots in 24 shelterwood cutting units (8 sets of 3 units each). Red fir composed 80 percent (2231) of the surviving seedlings; white fir composed the remainder (except for about 20 lodgepole and 2 Jeffrey pine). Forty percent (1103) of the seedlings had been browsed by deer and were not used in analyses of seedling height. White fir seemed to be slightly preferred, since proportionally more white fir than red fir (49 to 37 percent respectively) suffered damage.

Two common observations concern natural regeneration: first, success depends largely upon a good seed crop; second, seed production varies greatly from year to year. Measured cone production on Swain Mountain follows the general pattern of large variation from year to year *(fig. 1)* (Gordon 1978). The first year (1970) of shelterwood cutting was a poor cone year, the second year (1971) was the second best on record, and the third year (1972) produced no measurable cone crop. For this reason, the first analysis was to compare seedling density by shelterwood density and year of cutting (1971 and 1972).

All plot data (browsed and unbrowsed) from the 24 units were used, expressed as total seedlings per ha. No statistically significant ($p = <0.05$) effect appeared for treatment, year, or interaction between treatment and year *(table 1)*. Power of the test was 0.94, sufficient to accept the hypothesis of no difference. The alternative used to calculate power of the test was that seedling numbers under the 25, 50, and 75 trees per ha (10, 20, 30/acre) would be in the ratio of 1:1.5:1.75, respectively. Ratios were based on general observations of natural regeneration. The lack of shelterwood density effects on seedling density agrees with the 1975 analysis (Gordon 1979).

To determine effects of shelterwood density on seedling height, the 1973 unbrowsed seedlings were divided into three age classes (1 to 3, 4 to 5, and 6 to 7 years) and mean heights calculated for each class. Results of analysis of variance and Tukey tests are displayed in *tables 2 and 3*.

Analysis of mean seedling heights for all ages combined indicated no effect of treatment/year interaction but indicated a significant effect of shelterwood density on seedling height. Comparison of means using the Tukey test showed

Table 1—*Analysis of variance of number of seedlings*

Test	Test statistic		Critical F			Statistically significant
	Calculated[1]	Value	Value	p	d.f.	
No. seedlings						
Year (block)	msT/msB	1.41	5.99	0.05	1,6	No
Treatment	msT/msE	2.46	3.89	0.05	2,12	No
Year-treatment	msYT/msE	0.53	3.89	0.05	2,12	No

[1]ms = mean square; Y = year; T = treatment; E = error; YT = year/treatment interaction.

Table 2—*Analysis of variance of seedling heights*

Test	Test statistic		Critical F			Statistically significant
	Calculated[1]	Value	Value	p	d.f.	
			Treatment			
Year (block)	msYT/msE	1.30	2.18	0.05	2,24	No
Treatment	msT/msTB	21.50	3.89	0.05	2,12	Yes
Age-treatment	msAT/msE	9.00	2.78	0.05	4,24	Yes
			Treatment within age class			
1 (1-3 years)	msT/msE	4.62	3.89	0.05	2,12	Yes
2 (4-5 years)	msT/msE	15.35	3.89	0.05	2,12	Yes
3 (6-7 years)	msT/msE	22.66	3.89	0.05	2,12	Yes
			Effect of year (block) within age class			
1 (1-3 years)	msB/msE	1.08	3.00	0.05	6,12	No
2 (4-5 years)	msB/msE	3.63	3.00	0.05	6,12	Yes
3 (6-7 years)	msB/msE	0.88	3.00	0.05	6,12	No

[1]ms = mean square; Y = year; T = treatment; E = error; YT = year/treatment interactions; AT = age/treatment interaction.

that seedlings growing under 25 trees/ha (10/acre) were taller on average than those under either 50 or 75 trees/ha (20 or 30/acre) *(tables 3 and 4).*

A comparison of age groups for all treatments and years showed no significant interaction between treatment and year of cutting but, as would be expected, seedling age significantly affected seedling height. Seedlings in age class 1 (1 to 3 years) were statistically indistinguishable in height from seedlings in age class 2 (4 to 5 years). Both age classes 1 and 2 were statistically different than age class 3 (6 to 7 years), with the older age class clearly taller.

Comparison of treatments within each age class indicated that, in all three classes, treatment effects were significant *(table 2).* Each age class was analyzed by Tukey tests to identify differences *(table 3):*

- Age class 1 seedlings grown under 25 trees per ha (10/acre) were taller than seedlings grown under 75 trees per ha (30/acre) but were statistically not different from seedlings grown under 50 trees/ha (20/acre). Seedlings grown under 50 trees per ha (20/acre) were statistically not different from those under 75 trees per ha (30/acre).
- Age class 2 (4 to 5 years) seedlings under treatment 1 (low shelterwood density) were significantly taller than those under treatments 2 and 3 (medium and high density shelterwoods), while those grown under medium density were not different from those under high density shelterwood.

Table 3—*Tukey test of seedling heights*

Test	Difference in means	Confidence interval[1]	Statistically significant
	cm		
		Treatment effects	
25-50/ha	8.63	3.85	Yes
25-75/ha	11.04	3.85	Yes
50-75/ha	2.42	3.85	No
		Treatment between age classes[2]	
1-2	4.37	5.92	No
1-3	22.50	5.92	Yes
2-3	18.13	5.92	Yes
		Treatment within age class	
Class 1			
25-50/ha	2.25	2.38	No
25-75/ha	3.25	2.38	Yes
50-75/ha	1.00	2.38	No
Class 2			
25-50/ha	5.58	2.66	Yes
25-75/ha	6.25	2.66	Yes
50-75/ha	0.87	2.66	No
Class 3			
25-50/ha	10.25	8.01	Yes
25-75/ha	23.63	8.01	Yes
50-75/ha	5.38	8.01	No

[1]95 pct joint confidence interval (alpha = 0.05) in the difference in means, degrees of freedom = 12.

[2]Age class 1 = 1 to 3 years; age class 2 = 4 to 5 years; age class 3 = 6 to 7 years.

Table 4—*Mean seedling heights, by age classes*

Age classes[1]	Treatment[2]		Mean height[3]		Standard error	
	per ha	*(per acre)*	*cm*	*(in)*	*cm*	*(in)*
			Combined			
All ages	25	(10)	23.3a	(9.4a)	1.3	(0.5)
All ages	50	(20)	15.2b	(6.0b)	1.3	(0.5)
All ages	75	(30)	12.8b	(5.0b)	1.3	(0.5)
			Between ages			
Class 1	All		9.2a	(3.2a)	1.5	(0.6)
Class 2	All		12.5a	(4.9a)	1.5	(0.6)
Class 3	All		30.7b	(12.1b)	1.5	(0.6)
			Within ages			
Class 1	25	(10)	10.0a	(3.9a)	0.5	(0.2)
Class 1	50	(20)	7.8ab	(3.1ab)	0.5	(0.2)
Class 1	75	(30)	6.8b	(2.7b)	0.5	(0.2)
Class 2	25	(10)	16.9a	(6.7a)	0.5	(0.2)
Class 2	50	(20)	11.5b	(4.5b)	0.5	(0.2)
Class 2	75	(30)	10.6b	(4.2b)	0.5	(0.2)
Class 3	25	(10)	44.6a	(17.6a)	1.5	(0.6)
Class 3	50	(20)	26.4b	(10.4b)	1.5	(0.6)
Class 3	75	(30)	21.0b	(8.3b)	1.5	(0.6)

[1]Age class 1 = 1 to 3 years; age class 2 = 4 to 5 years; age class 3 = 6 to 7 years.

[2]Shelterwood trees per ha (acre).

[3]Means with the same suffix are not statistically different.

• Age class 3 seedlings (6 to 7 years) expressed the same differences as those in age class 2.

• Age class 2 only showed a significant interaction of age and block (year). The reason for, or importance of, this interaction is not clear.

The difference in seedling heights between treatments *(table 4)* is biologically meaningful as well as statistically *(table 2)* significant at this age.

The pattern of regeneration over time is important to the forester and may be critical for planning, if time and stocking standards are imposed by regulation or policy. In the following analysis, the age of each seedling (as of 1978) was expressed as year of origin following cutting. For example, on an area cut in 1970, a seedling which was 5 years old in fall 1978 originated 4 years after cutting. A similar seedling on an area cut in 1971 originated 3 years after cutting. Both are products of the 1973 seed crop.

Using a minimum of 741 2-year-old seedlings per ha (300/acre) as a standard, all areas of 25 and 50 trees per ha (10 and 20/acre) and 89 percent of the areas of 75 trees per ha

Table 5—*Regeneration by years following harvest, 25 trees per ha (10/acre)*

Origin	Blocks 1	2	3	4	5	6	7	8	Mean	S.E.	Total
	Seedlings per ha										*pct*
Year 1	494	494	741	494	247	1236	15320	4695	2965	1838	14
Year 2	2224	5436	3212	741	1977	6672	17544	12108	6239	2057	29
Year 3	4695	7166	1730	1236	988	6425	7166	12355	5221	1377	24
Year 4	3459	5930	3954	2224	988	4695	2471	8649	4047	852	19
Year 5	2965	2965	3212	2471	0	2224	1730	2471	2256	363	11
Year 6	1236	1483	494	741	0	247	494	494	650	175	3
Year 7	0	247	247	247	0	0	247	0	124	240	1
Year 8	0	0	0	0	-	-	-	-	0	0	0
Total/ha	15073	23722	13591	8154	4201	21498	44972	40772	21498	14680	
Total/acre	6100	9600	5500	3300	1700	8700	18200	16500	8700	5941	
	Total seedlings (pct)										
Year 1	3	2	5	6	6	6	34	12	9	4	
Year 2	15	23	24	9	47	31	39	30	27	4	
Year 3	31	30	13	15	24	30	16	30	24	3	
Year 4	23	25	29	27	24	30	16	30	24	3	
Year 5	20	13	24	30	0	10	4	6	13	4	
Year 6	8	6	4	9	0	1	1	1	4	1	
Year 7	0	1	2	3	0	0	1	0	1	0	
Year 8	0	0	0	0	-	-	-	-	0	0	

Table 6—*Regeneration by years after harvest, 50 trees per ha (20/acre)*

Origin	Blocks 1	2	3	4	5	6	7	8	Mean	S.E.	Total
	Seedlings per ha										*pct*
Year 1	1730	247	0	494	3707	3459	11614	3459	3059	1332	10
Year 2	3707	3707	1730	1236	5189	8649	22239	11861	7289	2478	23
Year 3	6672	8649	4201	5930	5934	5436	7907	8154	6609	540	21
Year 4	6425	9884	2224	9143	4201	8869	2224	8869	6486	1132	21
Year 5	6425	9143	1483	10131	1730	2471	3459	2224	4633	1225	15
Year 6	9143	4695	1236	5189	741	247	247	0	2565	1172	9
Year 7	1236	3459	741	1483	0	494	0	0	618	209	2
Year 8	494	0	0	247	-	-	-	-	185	119	<1
Total/ha	35930	37312	11614	33853	21498	29405	47690	34594	31474	10887	
Total/acre	14500	15100	4700	13700	9700	11900	19300	14000	12738	4406	
	Total seedlings (pct)										
Year 1	5	1	0	1	17	11	24	16	9	3	
Year 2	10	10	15	4	24	29	47	34	22	5	
Year 3	19	23	36	18	28	18	17	24	23	2	
Year 4	18	26	19	27	20	30	5	26	21	3	
Year 5	18	25	13	30	8	8	7	6	14	3	
Year 6	26	13	11	15	3	1	1	0	9	3	
Year 7	3	3	6	4	0	2	0	0	2	1	
Year 8	1	0	0	1	-	-	-	-	0	1	

Table 7—*Regeneration by years after harvest, 75 trees per ha (30/acre)*

Origin	Blocks 1	2	3	4	5	6	7	8	Mean	S.E.	Total
					Seedlings per ha						*pct*
Year 1	247	0	247	247	494	2471	25698	3459	4109	3116	14
Year 2	2471	741	2965	247	2718	5930	20509	10131	5715	2391	19
Year 3	5683	1977	10378	1977	6919	8896	6178	8649	6333	1076	21
Year 4	9143	1977	7413	4695	6672	6178	1236	7907	5641	997	19
Year 5	8154	2718	7660	7907	1977	2718	2471	3459	4633	971	16
Year 6	2718	3707	6178	4942	247	741	247	1236	2503	800	8
Year 7	247	741	988	2224	0	247	0	247	583	264	2
Year 8	494	0	0	247	-	-	-	-	185	119	<1
Total/ha	29158	11861	35830	22486	19027	27181	56339	35088	29621	13454	
Total/acre	11800	4800	14500	9100	7300	11000	22800	14200	11988	5445	
					Total seedlings (pct)						
Year 1	1	0	1	1	3	9	46	10	9	5	
Year 2	1	6	8	1	14	22	36	29	15	5	
Year 3	19	17	29	9	36	33	11	25	22	4	
Year 4	31	17	21	21	35	23	2	23	22	4	
Year 5	29	23	31	35	10	10	4	10	18	4	
Year 6	9	31	17	22	1	3	0	4	11	4	
Year 7	1	6	3	10	0	1	0	1	3	1	
Year 8	2	0	0	1	-	-	-	-	<1	1	

(30/acre) were regenerated by the third year following cutting. By the fourth year, all areas exceeded this level. The times expressed are conservative; the data are only for seedlings surviving in 1978. Additional seedlings are not recorded that may have existed in any particular year but are now gone. The single set of three cutting areas installed in 1972 is included in these figures.

The origin of seedlings, by year following harvest, on each block in each treatment was determined *(tables 5-7).* Although the variation between blocks in any given year (as evidenced by the standard errors of the mean) is too large to draw a clear conclusion, a pattern is apparent *(fig. 1).* In all cases, relatively few seedlings became established during the first year following harvest. More originated in the second year and again during the third year. After the fourth or fifth year after harvest the number of new seedlings decreased rapidly.

A 16-year study of cone production on Swain Mountain Experimental Forest (Gordon 1978) covered the years 1970 to 1975 *(fig. 2).* Comparison of annual cone production with the number of seedlings that originated each year reveals a surprising lack of correspondence.

On blocks 1 through 4, cut to 25 trees per ha (10/acre) in 1970, roughly a quarter of the seedlings that survived until 1978 originated in the third year after harvest (1973) and were from the 1972 cone crop. Gordon's data indicate no measurable cone crop for either species in 1972 and no evidence in the literature suggests that seed of either species remain viable in the duff beyond the first spring.

Blocks 5 through 8, cut in 1971, exhibit the same general relationship for seedlings originating in the second year after harvest (also the 1972 seed crop). Similarly, for the next year on the same areas, total new seedlings remain high while the white fir cone crop rises to an average of over 75 cones per tree and the red fir crop averages only a trace. However, the majority of regeneration is still red fir. On the other hand, the effect of the large crop borne by both species in 1971 is evident in all blocks *(table 8).* The same general pattern of seedling establishment appears in areas cut to 50 and 75 trees per ha (20 and 30/acre).

The current data do not allow testing of any hypothesis to explain this pattern and there is no way to determine from data collected in 1978 the actual number of seedlings that may have been present in any given year. However, a plausible hypothesis is suggested by Gordon (1978), who reported that

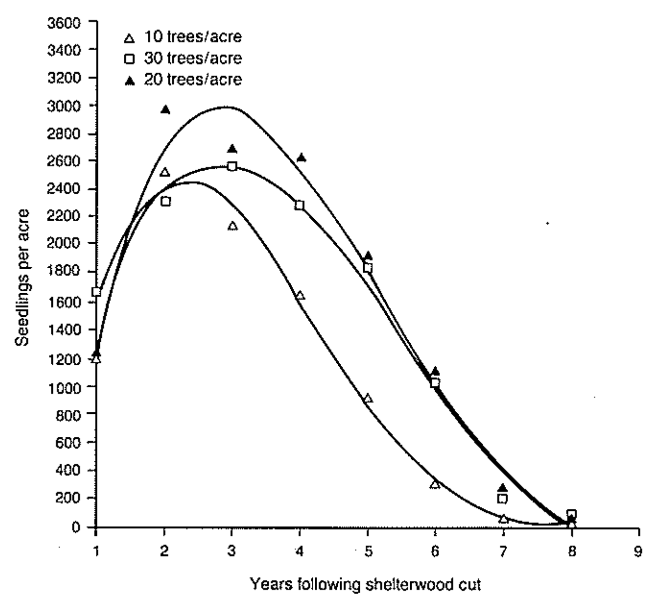

Figure 2—Origin of seedlings surviving in 1978 expressed as number of years after logging. All areas are combined under each shelterwood level. Curves are drawn for illustration only.

Table 8—*Percentage of seedlings, by seed year*

Origin	Blocks 1	2	3	4	5	6	7	8	Mean	S.E.
				25 trees per ha (10/acre)						
1970	3	2	5	6	-	-	-	-	4.0	0.9
1971	15	23	24	9	6	6	34	12	16.1	3.5
1972	31	30	13	15	47	31	39	30	29.5	4.0
1973	23	25	29	27	24	30	16	30	25.5	1.7
1974	20	13	24	30	24	22	5	21	19.9	2.7
1975	8	6	4	9	0	10	4	6	5.9	1.1
1976	0	1	2	3	0	1	1	1	1.1	0.4
1977	0	0	0	0	0	0	1	0	0.1	0.1
				50 trees per ha (20/acre)						
1970	5	1	0	1	-	-	-	-	1.8	1.1
1971	10	10	15	4	17	11	24	10	12.6	2.1
1972	19	23	36	16	28	29	47	34	29.3	3.4
1973	18	26	19	27	28	10	17	24	22.1	1.6
1974	18	25	13	30	20	30	5	26	20.6	3.1
1975	26	13	11	15	0	0	7	6	9.8	3.0
1976	3	3	6	4	3	1	1	0	2.6	0.7
1977	1	0	0	1	0	2	0	0	0.6	0.2
				75 trees per ha (30/acre)						
1970	1	0	1	1	-	-	-	-	0.3	0.3
1971	1	6	8	1	3	9	46	10	10.5	5.2
1972	19	17	29	9	14	22	36	29	21.9	3.2
1973	31	17	21	21	36	33	11	25	24.4	3.0
1974	28	23	21	35	35	23	2	23	23.8	3.7
1975	9	31	17	22	10	10	4	10	14.1	3.1
1976	1	6	3	10	1	3	0	4	3.3	1.2
1977	2	0	0	1	0	1	0	1	0.6	0.2

the mature dominant trees used in his cone study could respond to the release afforded by the edge of a clearcut strip. White fir could increase cone production by 1.5 to 6.7 times. Red fir response was much less. At maximum, red fir doubled its cone production and in only 3 of 10 years did cones produced on "released" trees exceed that on "unreleased" trees in the stand interior.

Given the lack of any evidence that fir seed carry over from year to year, a likely hypothesis is that trees left in the shelterwood cuttings were stimulated to produce more cones and seeds than trees in the uncut forest. The decline in new seedling establishment following the fourth year after harvest may well result from competition with large numbers of seedlings and brush and grass that became established following initial site preparation. Studies are being installed at Swain Mountain and elsewhere to test this possibility. If this suggestion proves correct, it may not be necessary to schedule shelterwood cuts to coincide with good cone crops, thus allowing considerably more flexibility in planning.

Stability of leave trees has long been an issue for partial cutting in true firs. Research at Swain Mountain identified characteristics of trees that would both produce seed and remain standing long enough to achieve regeneration (Gordon 1978, 1979). Shelterwood trees in the study were chosen using these criteria. Less than 1 percent of the 2300 trees left on a total of 46.5 ha (115 acres) had blown down or suffered significant snow damage in the 6 to 8 years since shelterwood cuts were made.

CONCLUSIONS

If leave trees are carefully chosen for their capacity to produce seed and to remain standing after shelterwood cut, as few as 25 trees per ha (10/acre) were adequate to regenerate old-growth stands of red fir and white fir. From the viewpoint of obtaining regeneration, there is no apparent need nor justification for leaving more trees as part of shelterwood cover. Additional trees simply make protection of the established regeneration more difficult during removal of shelterwood. In addition, if the shelterwood is left standing for more than 4 years, regeneration suffers less under 25 trees per ha (10/acre) than at the other levels tested. In areas like Swain Mountain, where the forest cover is a mixture of red and white firs, the regeneration is likely to be predominantly red fir even if red fir represents only a minor component of the shelterwood.

Clearly, the establishment of seedlings did not follow the general pattern of cone production on Swain Mountain Experimental Forest which suggests that, if appropriate seed trees are chosen, it may not be necessary to schedule harvesting or site preparation to coincide with a "good" seed year. However, before any realistic conclusion can be drawn, actual data must be collected on seed production patterns in shelterwoods.

REFERENCES

Franklin, Jerry F. **A guide to seedling identification for 25 conifers of the Pacific Northwest.** Portland, OR: Pacific Northwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1961. 65 p.

Gordon, Donald T. Records on file at Pacific Southwest Forest and Range Experiment Station, Redding, CA; 1973.

Gordon, Donald T. **White and red fir cone production in northeastern California: report of a 16-year study.** Res. Note PSW-330. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1978. 4 p.

Gordon, Donald T. **Successful natural regeneration cuttings in California true firs.** Res. Paper PSW-140. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1979. 14 p.

Laacke, Robert J.; Tomascheski, Jeanne H. **Shelterwood regeneration of true fir: conclusions after 8 years.** Res. Paper PSW-184. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 1986. 7 p.

Shelterwood cuttings on Swain Mountain Experimental Forest were measured to determine performance six to eight years after the shelterwood cutting and before shelterwood removal. Use of appropriate selecting criteria minimized windthrow of seed trees. Regeneration remained red fir, even where the major seed source was white fir. Density of seed trees may affect seedling growth only after the fourth year. Adequate regeneration can be attained and maintained at 25 trees per hectare (10/acre). In addition, the total number of seedlings produced each year was apparently not related to cone production in nearby stands.

Retrieval Terms: Abies, natural regeneration, red fir, seed tree, shelterwood, true fir, white fir