NATURAL AND PLANTED REGENERATION OF INTERIOR DOUGLAS-FIR IN WESTERN MONTANA

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ABSTRACT

Throughout the range of interior Douglas-fir both natural and artificial means are used to regenerate disturbed areas. Three study sites in western Montana (Coram Experimental Forest, Miller Creek Demonstration Forest, and Newman Ridge study area), document the establishment and early growth of natural and planted Douglas-fir regeneration. Harvest methods were clearcutting at each study site, and shelterwood and group selection (small openings) cutting at Coram. Site treatments were prescribed burning and no burning at Coram and prescribed burning only at Miller and Newman. Natural regeneration began from seed from onsite or nearby trees. Plantations originated from 2-0 bare root seedlings grown at the USDA Forest Service's Coeur d'Alene Nursery and were planted for several consecutive years following treatment. Stocking, number of trees per acre, total height, and average annual height for Douglas-fir are shown in this paper.

Douglas-fir natural regeneration predominated on most cutover areas—a result of the high proportion of Douglas-fir seed source, seed production while site was receptive, good seed dispersal, and reasonable seedling survival. Douglas-fir planted within four years following site treatment were significantly taller and the average annual height growth was greater than the tallest Douglas-fir natural regeneration after 15-20 years. Although individual tree height growth was greater, some Douglas-fir plantations had high mortality.

Keywords: Douglas-fir, natural regeneration, planting, height growth

INTRODUCTION

Interior Douglas-fir (*Pseudotsuga menziesii* var. *glauca* [Beissn.] Franco), sometimes called Rocky Mountain Douglas-fir or inland Douglas-fir (Little 1979), is a valuable component of many forests in Montana. It is a good seed producer (Boe 1954) and usually regenerates naturally after timber harvest. Bare root and containerized seedlings are frequently planted to assure its presence in stands primarily regenerated to other species or to decrease the time for its establishment. But there is a nagging concern that in the long run, planted interior Douglas-fir from natural seed sources may not grow as well as natural regeneration. So, what is the growth of planted stock compared to natural regeneration? This paper compares regeneration and early height growth of natural and planted Douglas-fir at three locations in western Montana.

STUDY AREAS

Three studies within the western larch (*Larix occidentalis*) forest cover type (Eyre 1980) compared regeneration success and height growth of planted and naturally regenerated Douglas-fir on the Coram Experimental Forest (Coram), Miller Creek Demonstration Forest (Miller), and Newman Ridge (Newman) in western Montana (Figure 1).

Figure 1.—Locations of the Coram Experimental Forest, Miller Creek Demonstration Forest, and Newman Ridge study areas in western Montana.

Coram

The Coram study (Shearer 1980) was conducted on an east-facing slope in Abbot Basin (Lat. 48°25' N., Long. 113°59' W.) on the Hungry Horse Ranger District, Flathead National Forest (Figure 1). Slopes range from 30-80%, and elevation ranges from 3,900-5,200 feet mean sea level (m.s.l.). Soils are derived from impure limestone and underlying material of loamy-skeletal soil families (Klages *et al.* 1976), and the surface loess layer ranges from 1-2 inches thick. Annual precipitation averages about 31 inches.

The study area is mostly within the *Abies lasiocarpa/Clintonia uniflora* habitat type (Pfister *et al.* 1977). The

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following phases are represented: *Aralia nudicaulis, Menziesia ferruginea, Clintonia uniflora,* and *Xerophyllum tenax* (Bernard L. Kovalchik 1974, unpublished, on file at Forestry Sciences Laboratory, Missoula, MT). The *Abies lasiocarpa/Oplopanax horridum* h.t. is found along moist draws in the upper clearcut, and the *Tsuga heterophylla/Clintonia uniflora* h.t. *Aralia nudicaulis* phase is found on the gentle topography in the lower clearcut.

Species composition within the virgin forest, in percent, was: Douglas-fir 58, larch 20, subalpine fir (*Abies lasiocarpa*) 12, Engelmann spruce (*Picea engelmannii*) 7, and four other species 3. Six blocks were logged in 1974, including two clearcuts (14 and 17 acres), two shelterwoods (35 and 22 acres), and two blocks of group selection cuttings with eight groups each (groups average 0.8 acre each). Each block was divided into four subblocks, each of which received a different level of timber and residue utilization. The tree cutting requirements, utilization standard and site treatment (Artley *et al.* 1978) are shown for only the three subblocks that were planted with Douglas-fir:

Subblock	Trees cut	Utilization standard	Site treatment
1	All trees except designated overstory shelterwood trees	All material (live and dead, standing and down) to 3 inch diameter, 8-foot length, and 1/3 sound, removed	Burned
2	All trees except designated overstory shelterwood trees	Sawtimber material (live and recently dead) to 1974 Forest Service standards of 7 inch d.b.h., 8-foot length, and 1/3 sound, removed	Burned
3	All trees except designated overstory shelterwood trees	All material (live and dead, standing and down(to 1 inch diameter (intensive fiber utilization)	Unburned

Two of the subblocks of each unit were prescribed burned in early September 1975 (Artley *et al.* 1978). None of the units were burned within prescription because the above-average summer precipitation limited fuel drying, and burning could not be delayed for a year. In fact, the lower elevation shelterwood was not burned because fuels were excessively moist.

Each May from 1976 through 1979, 25 2-0 bare root Douglas-fir were auger planted on subblocks 1, 2, and 3 of each cutting block at a 6-foot average spacing. No planting was done on subblock 4 because the understory trees were reserved for future growth. Establishment and growth of natural regeneration and plantations were recorded periodically from 1976 through 1987.

Miller

Miller is located in northwestern Montana (Figure 1) in the adjacent Miller Creek and Martin Creek drainages on the Tally Lake Ranger District, Flathead National Forest (Lat. 48° 31' N., Long. 114° 43' W.). Elevation ranges from 4,200-5,000 feet m.s.l. at Miller. The clearcuts are located from stream bottom to ridgetop on gentle slopes that average 24% (range 9-35%). Soils have developed in glacial till from argillites and quartzites of the Wallace (Belt) Formation and are overlain with a 0.5- to 2.5-inch layer of loess (DeByle 1981).

Cool, moist conditions prevail with about 25 inches of annual precipitation. The *Abies lasiocarpa/Clintonia uniflora* habitat type (Pfister *et al.* 1977) predominates. Three phases were identified: *Xerophyllum tenax* on the drier south- and west-facing slopes, *Menziesia ferruginea* on the cooler middle and upper east- and north-facing slopes, and *Clintonia uniflora* on west-, east-, and north-facing slopes on the remaining sites.

Species composition of the virgin forest, in percent, was: Engelmann spruce 31, Douglas-fir 31, western larch 26, subalpine fir 6, and lodgepole pine (*Pinus contorta* var. *latifolia*) 6. Several 10-acre units were clearcut on north-, east-, south-, and west-facing slopes in 1966 and 1967, then prescribed burned in 1967 or 1968 (Shearer 1975). Some units were burned in a wildfire on August 23, 1967.

About 50 seedlings of bareroot Douglas-fir were auger planted each year from 1970-1973. Establishment and growth of post-treatment natural regeneration and plantations were recorded for 13 units at about 5-year intervals through 1984; four of these units were remeasured again in 1989.

Newman

The Newman plots are located in western Montana near the Idaho border (Figure 1) on the Lolo National Forest (Lat. 47°17' N., Long. 115°17' W.). The clearcuts lie along Newman Ridge, the high divide separating the Two-Mile and Ward Creek drainages. Slopes range from 40-55% in average steepness (Table 1); some pitches exceed 100%. Elevations range from 4,300-5,300 feet m.s.l. Soils were developed in place or in colluvium from argillites and quartzites of the Belt formation, and the loess surface ranges from 2-3 inches in thickness (DeByle 1981).

Six distinct habitat types (Pfister *et al.* 1977) are found from the cool, moist *Thuja plicata/Clintonia uniflora* h.t., *Menziesia ferruginea* phase on concave north and northeast aspects, to the warm and dry *Pseudotsuga menziesii/Physocarpus malvaceus* h.t., *Physocarpus malvaceus* phase on convex southwest-facing slopes. The other habitat types are *Abies grandis/Clintonia uniflora* h.t. on concave east, northwest, and protected south-facing slopes; *Abies grandis/Xerophyllum tenax* h.t. on upper west-facing aspects; *Abies lasiocarpa/Clintonia uniflora* h.t., *Menziesia ferruginea* phase on the north-facing slopes along the ridge lines; and *Pseudotsuga menziesii/Vaccinium globulare* h.t., *Xerophyllum tenax* phase on upper south aspects (Shearer 1982).

Species composition of the virgin stand, in percent, was: Douglas-fir 34, larch 26, lodgepole pine 17, ponderosa pine (*Pinus ponderosa* var. *scopulorum*) 9, grand fir (*Abies grandis*) 7, spruce, white pine (*Pinus monticola*), and western redcedar (*Thuja plicata*) 7. Seven units, ranging in size from 32-58 acres, were clearcut in 1968 and 1969 on north-, east-, south-, and west-facing slopes, and slash was burned in 1969 and 1970 (Table 1).

Douglas-fir plantations were established on all clearcuts in May of successive years after prescribed burning. Five

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Table 1.—Range in aspect and average slope by study area and cutting method: eight units at Coram Experimental Forest, Flathead National Forest; four clearcuts at Miller Creek, Flathead National Forest; seven clearcuts at Newman Ridge, and Lolo National Forest (adapted from Shearer 1982).

Cutting method, unit ID	Size	Date burned	Duff reduction	Range in aspect	Mean Slope
	Acres		Percent	Degrees	Percent
Coram					
Clearcut, lower	14	9/12/75	27	213 - 314	55
Clearcut, upper	17	9/08/75	26	212 - 320	60
Shelterwood, lower	35	no burn	0	212 - 320	52
Shelterwood, upper	22	9/09/75	12	219 - 312	61
Group selection, lower	8	9/13/75	48	268 - 335	55
Group selection, upper	6	9/11/75	28	240 - 350	58
Miller Creek					
Clearcut, North-8	12	9/10/68	[1]--	340 - 20	20
Clearcut, East-10	10	9/09/68	42	70 - 128	18
Clearcut, West-7	11	8/24/67	[2]--	141 - 314	13
Clearcut, West-8	8	7/24/68	40	193 - 250	24
Newman Ridge					
Clearcut, North-1	40	7/14/69	80	300 - 60	55
Clearcut, East-1	33	9/28/70	69	90 - 170	50
Clearcut, East-3	38	7/25/69	[2]--	65 - 150	55
Clearcut, South-1	45	6/04/69	65	170 - 210	40
Clearcut, South-3	44	9/15/70	90	180 - 240	45
Clearcut, West-1	58	6/01/69	79	240 - 280	50
Clearcut, West-3	32	9/28/70	69	270 - 280	45

[1]Burned during prescribed fire, no data taken.
[2]Burned during wildfires, no data taken.

clearcuts were burned in 1969 and the other two were burned in 1970. Initially, more than 500 2-0 bare root Douglas-fir were planted. In succeeding years through 1975 about 100 bare root Douglas-fir were auger planted on each of the seven units. Establishment and growth of these plantations and natural regeneration were monitored at about 5-year intervals through 1984 on the clearcuts.

METHODS

Natural Regeneration

Stocking and the number of seedlings per acre of naturally regenerated Douglas-fir and all conifer seedlings greater than 0.5 foot tall (established), were estimated on systematically located temporary 1/300-acre circular plots. Natural regeneration was sampled most recently on Coram in 1987 (12 years following prescribed fires in 1975) on five horizontal rows, 100 feet apart, with 15 plots each spaced 50 feet apart. At Miller, four clearcuts were sampled in 1989 (21 years after prescribed fires in 1968), each with 20 permanent plots at 66-foot intervals on three transects oriented vertically on the slope, and at least 200 feet between transects. Seven clearcuts were sampled at Newman in 1984 (14 years following prescribed fires in 1970), each with from 100-200 temporary plots located systematically throughout each clearcut, 100 feet apart on horizontal transects, and 200 feet between transects.

The mean total height of the tallest Douglas-fir on each unit was computed by averaging the height of the tallest seedling or sapling on each plot. Age of the sample trees was not determined when the plots were measured, so age was estimated as the difference in years between the year of the first heavy cone crop that disseminated seed (conifer seedfall was measured at the three sites) after treatment. Dividing the total height of each sample tree by the approximated age gave the mean annual height growth.

Plantations

In May of each year (1976 through 1979 at Coram, 1970 through 1973 at Miller, and 1970 through 1975 at Newman), 2-0 Douglas-fir bare root stock produced at the USDA Forest Service's Coeur d'Alene Nursery was auger planted at about 6-foot average spacing. The mean height of the surviving trees was determined for each year of planting by averaging the most recent total height measurements. The average annual height growth of each planted tree was determined by dividing the total height by its age (including the 2 years in the nursery bed).

Height Growth Comparisons Between Natural and Planted Trees

The "TTest" procedure (SAS Institute Inc. 1985) was used to compute a t statistic (both $P = 0.05$ and $P = 0.01$) to test the hypothesis for the last measurement at each study area: the mean height of the tallest Douglas-fir natural regeneration and the mean height of surviving Douglas-fir for each year of planting are equal. Some bias may occur because the average height of the natural regeneration is based on the tallest Douglas-fir on each plot, whereas the average height of the planted trees is based on the height of all survivors at the last measurement.

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RESULTS

Natural Regeneration—Stocking and Amount

Douglas-fir regenerated most sites after harvest cutting when seed was available. About a third of the volume of the adjacent uncut timber at each study area was Douglas-fir, which provided considerable seed. Sites that were treated by burning or scarified when logs were moved by cables to the roads (mostly at Coram) enhanced establishment of natural regeneration.

Coram

On the east-facing slope at Coram, the abundant nearby residual Douglas-fir provided much seed for natural regeneration on all cutting units. Douglas-fir occurred on 97% of the regenerated plots on prescribed burned subblocks and on 78% of the regenerated plots on unburned subblocks (Table 2). Microsites that were scarified during yarding enhanced seedling establishment compared to adjacent undisturbed litter and duff. Percent composition of the regeneration on prescribed burned and unburned subblocks was:

Species	Burned	Unburned
Douglas-fir	84	71
Subalpine fir	2	19
Western larch	9	4
Engelmann spruce	3	2
Western hemlock	1	2
Others	1	2
	100	100

Miller

Douglas-fir within the old-growth timber bordering most clearcuts at Miller dispersed enough seed into the openings to maintain it as a major component in the new stands. But Douglas-fir natural regeneration decreased when other species predominated in the seed source of the nearby uncut forest (Table 3). Englemann spruce and subalpine fir predominated in the residual forest bordering clearcut North-8 (Table 4); Douglas-fir made up only 10% of the natural regeneration, compared to 30-45% on the other three clearcuts. Engelmann spruce and subalpine fir composed 77% of natural regeneration on the north-facing clearcut but only 8-40% on the other clearcuts.

Table 2.—Percent stocking and number of naturally established[1] Douglas-fir and all conifers combined per acre by unit, harvest method, and subblock treatment[2], Coram Experimental Forest, 1987.

Subblock treatment	Stocking		Trees per acre	
	Douglas-fir	All species	Douglas-fir	All species
	—Percent—		—Number—	
Shelterwood (Lower)				
1 (unburned)	65	75	1,710	2,055
2 (unburned)	60	73	1,420	1,720
3 (unburned)	90	95	7,200	7,695
Shelterwood (Upper)				
1 (burn)	80	80	975	1,245
2 (burn)	75	80	885	1,485
3 (unburned)	73	80	1,100	1,360
Group Selection (Lower)				
1 (burn)	89	100	2,567	2,700
2 (burn)	100	100	5,567	5,683
3 (unburned)	50	67	600	750
Group Selection (Upper)				
1 (burn)	72	72	1,300	1,417
2 (burn)	56	56	1,183	1,367
3 (unburned)	17	33	117	1,360
Clearcut (lower)				
1 (burn)	100	100	4,815	5,490
2 (burn)	100	100	2,700	3,580
3 (unburned)	50	60	570	630
Clearcut (Upper)				
1 (burn)	70	80	1,305	1,545
2 (burn)	70	70	1,020	1,140
3 (unburned)	53	60	280	360

[1]Established seedlings are at least 1 foot for western larch, lodgepole pine, and ponderosa pine, and at least 0.5 foot for all other species.
[2]See "Study Areas" section for definitions; lower shelterwood subblocks 1 and 2 not burned.

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Table 3.—Percent stocking and number of naturally established[1] Douglas-fir and all conifers combined; and average height (feet) of the tallest established[1] Douglas-fir seedling or sapling on each plot by clearcut unit, Miller Creek, 1989.

Clearcut	Stocking		Trees per acres		Average height of the tallest Douglas-fir	
	Douglas-fir	All species	Douglas-fir	All species	Height	Trees
	—Percent—		—Number—		Feet	Number
North-8	45	100	270	4,485	6.9	11
East-10	100	100	2,670	7,140	9.7	31
West-7	100	100	2,370	5,235	8.1	32
West-8	86	100	1,110	2,310	6.7	26

[1]Established seedlings are at least 1 foot for western larch, lodgepole pine, and ponderosa pine, and at least 0.5 foot for all other species.

Table 4.—Percent composition of established natural regeneration on four clearcuts at Miller Creek Demonstration Forest, 1989.

Species	North-8	East-10	West-7	West-8
Douglas-fir	10	31	45	30
Western larch	13	29	42	34
Engelmann spruce	50	31	7	27
Subalpine fir	27	9	1	9
Lodgepole pine	0	0	5	0
	100	100	100	100

Newman

Considerable Douglas-fir seed was produced in the uncut stands bordering the large clearcuts. Composition of the commercial timber harvested from these units, in percent, was: Douglas-fir 34, larch 26, lodgepole pine 17, ponderosa pine 9, grand fir 7, and all other species 7. Fifteen years after the harvest and burning treatments, Douglas-fir regeneration stocked 15-80% of the plots on the seven clearcuts (Table 5), and Douglas-fir seedlings were found on 44-86% of the stocked plots. Composition of Douglas-fir averaged 44% on the seven clearcuts, ranging from 21% on East-3 to 68% on South-1 (Table 6). Grand fir averaged 36% on the clearcutsfar above the proportion of timber volume removed. Because of low cone production, western larch regeneration was lower than expected.

Table 5.—Percent stocking and number of naturally established[1] Douglas-fir and all conifers combined; and average height (feet) of the tallest established[1] Douglas-fir on each plot by clearcut unit, Newman Ridge, 1984.

Clearcut	Stocking		Trees per acres		Average height of the tallest Douglas-fir	
	Douglas-fir	All species	Douglas-fir	All species	Height	Trees
	—Percent—		—Number—		Feet	Number
North-1	80	94	736	1,995	4.2	102
East-1	36	60	201	725	2.7	41
East-3	54	87	309	1,451	3.7	57
South -1	44	53	280	409	1.9	53
South-3	15	34	62	178	2.1	30
West-1	57	66	374	645	2.6	66
West-3	68	81	636	1,074	3.5	68

[1]Established seedlings are at least 1 foot for western larch, lodgepole pine, and ponderosa pine, and at least 0.5 foot for all other species.

Plantations—Survival

Plantation survival was more consistent for all years of planting at Coram than at Miller and Newman. Factors such as quality of stock received from the nursery, onsite storage of seedlings, and the planting methods may have individually or collectively influenced survival.

Coram

In 1987, average survival of planted Douglas-fir usually was higher on prescribed burned subblocks than on unburned subblocks (Table 7). Survival of trees planted in 1976, 1977, and 1978 was over 20% greater than of trees planted in 1979. The reasons for higher survival are not known, but competition with other vegetation for water and light may be a factor. Understory vegetation quickly colonized or recovered and provided heavy competition for moisture and light on the cutover areas. Prescribed burning seemed to set back the recovery period of onsite survivors from one to two seasons.

Miller

Survival in 1989 of Douglas-fir planted from 1970 through 1973 on the four clearcuts at Miller ranged from 34-91% (Table 8). In 1989, highest survival occurred among trees planted in 1971; lowest survival within plantations planted in 1970 and 1973. The reason for the pattern of survival was not apparent, but is probably an interaction between the condition of the stock when planted, quality of the planting, weather conditions after planting, and specific site factors.

Table 6.—Percent composition of established1 natural regeneration on seven clearcuts at Newman Ridge study area, 1984.

Species	North-1	East-1	East-3	South-1	South-3	West-1	West-3
Douglas-fir	37	28	21	68	34	58	59
Grand fir	40	55	60	18	52	14	10
Western larch	7	9	5	4	6	14	21
Ponderosa pine	5	7	6	9	7	14	1
W. white pine	5	1	2	1	1	0	6
Other	6	0	6	0	0	0	3

[1]Established seedlings are at least 1 foot for western larch, lodgepole pine, and ponderosa pine, and at least 0.5 foot for all other species.

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Table 7.—Number of Douglas-fir planted by year and their percentage of survival in 1987 by harvest method, subblock treatment[1], and year of planting; Coram Experimental Forest.

Subblock treatment	Year of planting							
	1976		1977		1978		1979	
	P[2]	S[2]	P	S	P	S	P	S
	No.	%	No.	%	No.	%	No.	%
Shelterwood (Lower)								
1 (unburned)	25	72	25	72	25	76	25	86
2 (unburned)	25	72	25	76	25	88	25	64
3 (unburned)	25	84	25	72	25	92	25	92
Shelterwood (Upper)								
1 (burn)	27	92	25	80	25	88	25	68
2 (burn)	25	84	25	68	25	76	25	68
3 (unburned)	25	84	25	80	25	72	25	32
Group Selection (Lower)								
1 (burn)	25	77	35	91	35	89	35	57
2 (burn)	50	80	50	94	50	84	50	42
3 (unburned)	38	87	39	90	39	67	39	31
Group Selection (Upper)								
1 (burn)	45	91	45	93	45	87	45	67
2 (burn)	48	90	48	83	50	82	49	88
3 (unburned)	47	83	47	89	47	77	47	23
Clearcut (Lower)								
1 (burn)	25	92	25	96	25	88	25	92
2 (burn)	25	92	25	96	25	100	25	64
3 (unburned)	25	84	25	92	25	52	25	56
Clearcut (Upper)								
1 (burn)	24	92	25	92	25	96	25	40
2 (burn)	25	92	25	92	25	88	25	76
3 (unburned)	25	80	25	80	25	84	25	40
Average of All Units								
Burned	88	89	88	66				
Unburned	81	81	76	53				

[1]See "Study Areas" section for description of subblock treatments; burning of subblocks 1 and 2 on the lower shelterwood was not done.
[2]P = planted; S = survival.

Table 8.—Number of Douglas-fir planted by year on four clearcuts and their survival (percent) in 1989, Miller Creek Demonstration Forest.

Clearcut	1970		1971		1972		1973	
	P[1]	S[1]	P	S	P	S	P	S
	No.	%	No.	%	No.	%	No.	%
North-8	50	64	50	76	46	72	50	76
East-10	50	58	45	91	50	78	50	46
West-7	53	48	50	84	50	86	50	68
West-8	50	52	43	84	50	54	50	34

[1]P = planted; S = survival.

Newman

At the last measurement made (1984) of the Douglas-fir plantations established from 1970 through 1975, survival in percent (Table 9) averaged: 24 for 1970, 37 for 1971, 54 for 1972, 38 for 1973, 51 for 1974 and 84 for 1975. Aspect had a strong influence on plantation survival at Newman Ridge. When all years are averaged, plantation survival was 73% on the north-facing clearcut, 52% on the east- and west-facing clearcuts, and 32% on the south-facing clearcuts.

Height Growth Comparisons of Natural and Planted Trees

Coram

The average total height of Douglas-fir natural regeneration (based on the mean of the tallest Douglas-fir on each plot) was 1.6 feet in 1987 and ranged from 2.9 feet on the burned lower group selection cuttings to 0.8 foot on subblock treatment 1 of the burned upper shelterwood (Table 10). When divided by age (12 years was used), the average annual height growth for natural regeneration was 0.13 foot and ranged from 0.24-0.07 foot (Table 11). Total and annual height averaged slightly greater within the clearcuts and group selection cuttings than within the shelterwoods. Also, the average total height was greater on the lower than on the upper clearcut and group selection cuttings.

In contrast, the average total height (Table 10) and the average annual height (Table 11) of Douglas-fir planted during the period from 1976 through 1979 was significantly greater (P = 0.01) than for the natural regeneration. Differences were greater for

Table 9.—Number of Douglas-fir planted by year on seven clearcuts and their survival (percent) in 1984, Newman Ridge study area.

Clearcut	1970		1971		1972		1973		1974		1975	
	P[1]	S[1]	P	S	P	S	P	S	P	S	P	S
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
North-1	553	33	101	64	99	83	100	81	100	78	100	97
East-1	514	22	106	48	94	61	100	44	100	75	100	77
East-3	508	18	98	31	98	57	100	47	100	34	100	93
South-1	615	23	78	37	100	43	100	16	100	36	100	56
South-3	[2]	---	633	24	99	24	100	9	100	1	100	80
West-1	590	24	99	[3] --	99	51	100	50	100	78	100	86
West-3	[2]	---	566	19	99	59	100	16	100	52	100	96

[1]P = planted; S = survival.
[2]Clearcuts South-3 and West-3 were burned in the fall of 1970—the first planting occurred in the spring of 1971.
[3]The 1971 Douglas-fir plantation on clearcut West-1 was not found in 1984.

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trees growing within the burned openings of clearcuts and group selection cuttings than on contrasting unburned sites. Height growth of planted trees growing on the lower clearcut and group selection cuttings was significantly greater than on the corresponding units at higher elevations. There was little, if any, difference in the height of planted trees growing within the unburned, closely utilized upper clearcut, group selection, or shelterwood units. These data demonstrate the importance of planting as soon after treatment as possible to realize the greatest benefits over waiting for natural regeneration.

In 1987, Douglas-fir planted on burned sites, with one exception, were taller and had greater average annual height growth than the natural regeneration (Tables 10, 11). The exception occurred within the 1979 plantation on treatment 2 of the upper shelterwood cutting. Total height and average annual height growth of planted Douglas-fir on unburned sites was also greater on the lower than on the upper cutting units.

Although height growth of planted Douglas-fir was enhanced on the burned subunits of the clearcuts and group selections, it was not increased for the natural regeneration component. Prescribed fires did not meet the burning prescription because of high moisture conditions, and Artley *et al.* (1978) forecast that the natural regeneration would be composed mostly of shade-tolerant species. Now it is apparent that the intense competition from herbs and shrubs that responded quickly following the logging and site preparation treatments is suppressing the growth of the natural regeneration. The larger planted trees were better able to take advantage of the brief postfire flush of nutrients and more favorable site conditions than was the natural regeneration.

Miller

The total height of Douglas-fir natural regeneration averaged 7.8 feet in 1989 on the four clearcuts and ranged from a mean of 6.7 feet tall on West-8 to a mean of 9.7 feet tall on East-10 (Table 12). The age of the tallest Douglas-fir was not determined in 1989, but most of the tallest regeneration on North-8, East-10, and West-8 probably came from seed produced in 1971, while many of the tallest trees on West-7 started from seed dispersed in 1967. When divided by these assumed ages in 1989 (18 years on clearcuts North-8, East-10 and West-8, and 22 years on clearcut West-7), the average annual growth was 0.38 foot on North-8, 0.54 foot on East-10, and 0.37 foot on West-7 and West-8.

Table 10.—Comparison[1] in 1987 of average total height (feet) of naturally regenerated and planted Douglas-fir by harvest method, subblock[2] treatment, and year of planting, Coram Experimental Forest.

Subblock treatment	Natural Regeneration		Year of planting							
			1976		1977		1978		1979	
	No.	Ht.	No.	Ht.	No.	Ht.	No.	Ht.	No.	Ht.
Shelterwood (Lower)										
1 (unburned)	11	1.7	18	3.6**	18	3.2*	19	3.1*	11	1.9
2 (unburned)	9	1.3	18	4.3**	19	4.2**	22	3.7**	16	2.3*
3 (unburned)	18	1.3	21	2.3**	18	2.2**	23	2.2**	23	2.2**
Shelterwood (Upper)										
1 (burn)	16	0.8	23	4.9**	20	4.2**	22	2.8**	17	2.3**
2 (burn)	15	1.4	21	3.6**	17	2.6**	19	2.9**	17	1.8
3 (unburned)	11	1.2	21	2.7**	20	2.6**	18	2.6**	8	1.7
Group Selection (Lower)										
1 (burn)	15	1.5	27	7.4**	32	5.8**	31	5.2**	20	3.9**
2 (burn)	17	2.9	40	7.9**	47	6.4**	43	4.9**	21	4.1*
3 (unburned)	9	1.0	33	5.2**	35	5.5**	26	4.1**	12	3.0**
Group Selection (Upper)										
1 (burn)	11	1.3	41	4.3**	42	4.4**	39	3.6**	30	3.3**
2 (burn)	9	1.6	43	6.2**	40	5.5**	41	4.3**	43	3.4**
3 (unburned)	3	2.1	39	3.6	42	3.0	36	2.8**	11	2.0
Clearcut (Lower)										
1 (burn)	20	1.9	23	7.2**	24	6.3**	22	5.0**	23	4.4**
2 (burn)	14	2.1	23	7.1**	23	6.0**	25	4.7**	16	3.7**
3 (unburned)	10	1.6	21	7.1**	23	5.5**	13	4.2**	14	3.4**
Clearcut (Upper)										
1 (burn)	14	1.6	22	4.4**	23	4.4**	25	3.9**	10	2.5*
2 (burn)	14	1.6	23	5.9**	23	4.8**	22	2.9**	19	2.8**
3 (unburned)	8	1.8	20	2.7	20	2.7*	21	2.5**	10	1.6

[1]Significant differences between natural and planted trees determined by T-tests: >0.05(*) and >0.01(**).
[2]Definitions in "Study Areas" section; lower shelterwood subblocks 1 and 2 not burned.

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Table 11.—Comparison[1] of average annual height growth (feet) between naturally regenerated and planted[2] Douglas-fir by harvest methods, subblock[3] treatment, and year of planting, 1987 (the sample size is the same as shown in Table 10), Coram Experimental Forest.

Subblock treatment	Natural regeneration	Year of planting			
		1976	1977	1978	1979
Shelterwood (Lower)					
1 (unburned)	0.14	0.26*	0.25*	0.26*	0.17
2 (unburned)	.11	.31**	.32**	.31**	.21**
3 (unburned)	.11	.17*	.17**	.19**	.20**
Shelterwood (Upper)					
1 (burn)	0.07	0.35**	0.33**	0.23**	0.21**
2 (burn)	.12	.26**	.20**	.24**	.17*
3 (unburned)	.09	.19**	.20**	.22**	.16
Group Selection (Lower)					
1 (burn)	0.13	0.53**	0.45**	0.43**	0.35**
2 (burn)	.24	.56**	.49**	.41**	.38**
3 (unburned)	.09	.37**	.42**	.34**	.27**
Group Selection (Upper)					
1 (burn)	0.11	0.30**	0.34**	0.30**	0.30**
2 (burn)	.13	.44**	.42**	.35**	.31**
3 (unburned)	.18	.25	.23	.23	.18
Clearcut (Lower)					
1 (burn)	0.16	0.52**	0.49**	0.42**	0.40**
2 (burn)	.18	.50**	.46**	.39**	.34**
3 (unburned)	.13	.50**	.42**	.35**	.31**
Clearcut (Upper)					
1 (burn)	0.13	0.32**	0.34**	0.33**	0.23*
2 (burn)	.13	.42**	.37**	.25**	.25**
3 (unburned)	.15	.19	.21	.21	.14

[1]Significant differences between natural and planted trees determined by T-tests: >0.05(*) and >0.01(**).
[2]To determine the average annual height growth: assume that tallest natural seedlings were age 12 in 1987. Total age of planted trees included 2 years in the nursery.
[3]Definitions in "Study Areas" section; lower shelterwood subblocks 1 and 2 not burned.

Table 12.—Comparison[1] of average total height (feet) and average annual height growth[2] (feet) of naturally regenerated and planted Douglas-fir by clearcut, Miller Creek Demonstration Forest, 1989.

Clearcut	Natural regeneration	Year of planting			
		1970	1971	1972	1973
North-8					
Number of trees	11	32	38	33	38
Average total height	6.9	13.4**	14.1**	8.9	9.7*
Average annual height	0.38	0.61**	0.67**	0.44	0.51*
East-10					
Number of trees	31	29	41	39	23
Average total height	9.7	15.4**	15.2**	13.4**	11.0
Average annual height	.54	.70**	.72**	.67**	.58
West-7					
Number of trees	32	24	42	43	34
Average total height	8.1	13.9**	13.3**	9.0**	8.2
Average annual height	.45	.63**	.63**	.47	.38
West-8					
Number of trees	26	26	36	27	17
Average total height	6.7	13.9**	10.8**	9.0**	8.2
Average annual height	.37	.63**	.51**	.45**	.43

[1]Significant differences between natural and planted trees determined by T-tests: >0.05(*) and >0.01(**).
[2]The average annual height growth assumed that the tallest natural Douglas-fir were age 18 in 1989 (from 1971 seedfall) on clearcuts North-8, East-10, and West-8; and were age 22 (from 1967 seedfall) on clearcut West-7. Age of planted trees included 2 years in the nursery.

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The 1970 plantations averaged over 14 feet in height, ranging from a mean of 13.4 feet on clearcut North-8 to a mean of 15.4 feet on clearcut East-10 (Table 12). Average annual height growth of the 1970 plantations averaged 0.64 foot and ranged from 0.61 foot on North-8 to 0.70 foot on East-10. Total height and average annual height growth of the Douglas-fir plantations decreased with each successive planting except on clearcut North-8.

Total height and average annual height growth were significantly greater for the 1970 and 1971 plantations than for the natural regeneration and the 1972 and 1973 plantations.

Newman

Total height of the tallest naturally regenerated Douglas-fir on each plot in 1984 averaged 3.0 within the seven clearcuts and ranged from a mean of 1.9 feet on South-1 to a mean of 4.2 feet on North-1 (Table 13). Average annual height growth averaged about 0.23 foot for the regeneration and ranged from 0.14 foot on clearcut South-1 to 0.32 foot on clearcut North-1.

Five of the seven clearcuts were first planted in 1970—these trees averaged 9.4 feet tall in 1984, ranging from a mean of 8.1 feet for clearcut East-3 to a mean of 11.1 feet for clearcut North-1. Total height of plantations decreased each successive year to an average on all units of 4.3 feet planted in 1975. Douglas-fir planted in 1975 ranged in height from a mean of 2.8 feet on clearcut West-1 to 5.8 feet on clearcut West-3. The average annual height growth on the five clearcuts planted in 1970 averaged 0.55 foot, ranging from 0.48 foot on East-3 to 0.65 foot on North-1. Douglas-fir planted in 1975 had an average annual height growth of 0.36 foot and ranged from 0.23 foot within the plantation on clearcut West-1 to 0.49 foot on clearcut West-3.

The total height and average annual height growth for all plantations were significantly greater than for natural regeneration except for the 1974 plantations on clearcuts North-1 and East-3 and for the 1975 plantation on clearcut West-1 (Table 13). Poor survival of Douglas-fir planted on clearcut South-3 in 1973 and 1974 precludes reliable comparisons of height with natural regeneration.

Table 13.—Comparison[1] of average total height (feet) and average annual height growth[2] (feet) of naturally regenerated and planted Douglas-fir by cutting unit, Newman Ridge study area, 1984.

Clearcut	Natural regeneration	Year of planting					
		1970	1971	1972	1973	1974	1975
North-1							
Number of trees	102	181	65	82	81	78	97
Average total height	4.2	11.1**	9.6**	7.2**	6.8**	4.3	5.2**
Average annual height	0.32	0.65**	0.60**	0.48**	0.48**	0.33**	0.43**
East-1							
Number of trees	41	113	51	57	44	75	77
Average total height	2.7	9.0**	10.0**	8.7**	5.1**	4.7**	4.4**
Average annual height	0.21	0.53**	0.63**	0.60**	0.37**	0.36**	0.37**
East-3							
Number of trees	57	90	30	56	47	34	93
Average total height	3.7	8.1**	6.8**	6.5**	5.8**	4.4	4.9**
Average annual height	0.29	0.48**	0.42**	0.43**	0.42**	0.34	0.41**
South-1							
Number of trees	53	140	29	43	16	36	56
Average total height	1.9	10.1**	7.7**	5.3**	3.8**	3.4**	3.0**
Average annual height	0.14	0.60**	0.48**	0.35**	0.27**	0.27**	0.25**
South-3							
Number of trees	30	Not	149	23	9	1	80
Average total height	2.1	planted	7.5**	5.0**	4.5**	5.5**	4.2**
Average annual height	.16		0.47**	0.33**	0.32**	0.42**	0.35**
West-1							
Number of trees	66	142	[3]	57	50	78	86
Average total height	2.6	8.6**	--	6.1**	5.5**	4.5**	2.8**
Average annual height	.20	0.51**	--	0.41**	0.39**	0.35**	0.23**
West-3							
Number of trees	68	Not	110	58	16	52	96
Average total height	3.5	planted	6.7**	6.7**	5.3**	6.0**	5.8**
Average annual height	.27	.42**	0.44**	0.38**	0.46**	0.49**	

[1]Significant differences between natural and planted trees determined by T-tests: >0.05(*) and >0.01(**).
[2]The average annual height growth was determined by dividing the total height in 1984 by the age of the tallest natural and planted trees. Although the age was not determined for these trees, the tallest probably originated from the 1971 seedfall and were age 13 in 1984. Total age of planted trees included 2 years in the nursery.
[3]The 1971 Douglas-fir plantation on clearcut West-1 was not found in 1984.

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DISCUSSION

Although some Douglas-fir seed is produced and dispersed each year, years of heavy seed production occur infrequently. During the course of these studies, heavy cone crops of all species were produced in 1971 and 1980. The abundant seed crop of 1971 provided most of the natural regeneration of Douglas-fir and other species on the clearcuts burned in 1968 at Miller and all seven clearcuts at Newman. The other clearcut at Miller was burned in 1967, and natural regeneration resulted from seed that was produced and disseminated that year as well as from 1971 seedfall. In 1980, another bumper seed crop was dispersed over these areas that greatly increased the number of Douglas-fir and other species per acre. At Coram, the 1980 cone crop provided the bulk of the natural regeneration following the 1974 harvesting and 1975 burning treatments.

Planting soon after site treatment takes advantage of the greater availability of and lower competition for moisture, light, and nutrients. Douglas-fir grown for local seed and planted as 2-0 seedlings soon after site treatment on the three study areas was taller than the average of the natural regeneration. If site preparation is timed with a good cone crop, the differences between height of natural and planted trees after 10 or 20 years will be less dramatic than if the first good seed crop is dispersed several years following site treatment.

These studies showed that Douglas-fir planted in western Montana up to 4 years after harvest and site treatment usually surpass the total height and average annual height growth of the tallest Douglas-fir natural regeneration and maintain this advantage for at least 15-20 years following treatment. Initial height growth was greater on lightly burned than on unburned sites. Also, height growth may be accentuated within clearcut and group selection openings compared to shelterwood cuttings.

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