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# douglas-fir reproduction in the shade of a managed forest

**Ernest Del Rio  
Alan B. Berg**



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## acknowledgments

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## **summary**

Growth was assessed for Douglas-fir reproduction which had established naturally beneath three intensities of overstory thinning in a 65-year-old stand of Douglas-fir on the east side of the Oregon Coast Range. The age of advanced reproduction ranged from 4 to 15 years. Understory environments were described in terms of sunlight, plant moisture stress, evaporative demand, air and soil temperatures, and vegetative cover. Daily sunlight reaching the reproduction, averaging 5 to 12 percent of full sun, best separated the three understory environments and correlated directly with the intensity of overstory thinning. Tree height and sunlight positively interacted with growth increment. Mean growth increased linearly with thinning intensity, and current growth highly correlated with growth and tree height of previous years.

## **introduction**

Thinning will play a major role in management of stands of young Douglas-fir (Berg 1976). Repeated thinning of the overstory during the past 20 years has enabled Douglas-fir to establish naturally in the understory of the Gerlinger State Experimental Forest near Falls City, Oregon. There we assessed vigor, in terms of growth, of Douglas-fir reproduction beneath different levels of overstory thinning. In addition, we examined thinning levels for differences in understory environments. This information, indicating how long Douglas-fir reproduction can grow in heavy shade, will be useful for management decisions about reforestation.



# study area

Located on the east side of the Coast Range about 64 kilometers northwest of Corvallis, Oregon, the George T. Gerlinger State Experimental Forest has a wet, mild climate. Annual precipitation averages about 200 cm, mostly as rain in the winter, and the frost-free growing season exceeds 200 days.

The soils have developed in residuum and colluvium from Eocene<sup>1</sup> sandstones, shales, and siltstones, as well as from Miocene<sup>2</sup> coarse-grained gabbro and diorite, both basic igneous intrusive rocks.<sup>3</sup> Strong, granular soils in the surface overlay moderate, subangular, blocky structure in the subsoil. The soils, moderately acid at the surface, become strongly acid in the subsoil.

Much of the sedimentary formation on the Black Rock Unit, where the study plots were located, occurs as a large, gentle, uneven slope that faces south. Aspects of the plots ranged from S45° W to S45° E, with slopes from 5 to 40 percent. Plot centers ranged from 332 to 579 m in elevation.

The area supported a 65-year-old stand of Douglas-fir that had regenerated naturally after clearcutting. Dominant trees stood about 40 m tall. Some western hemlock, grand fir, and western redcedar were scattered throughout the forest. The most common hardwoods were red alder, bigleaf maple, and Pacific dogwood. Shrub species included vine maple, Oregon grape, salal, and ocean spray. The flora of the area have been detailed by Witler.<sup>4</sup> (For a complete list of common and scientific names of the flora, see the CHECKLIST OF PLANTS.)

For 20 years, our 0.4 ha study plots had been repeatedly thinned to maintain basal areas between 23 to 30, 30 to 37, and 37 to 44 m<sup>2</sup>/ha; each of the three treatments was replicated four times. All thinned plots were yarded with horses to minimize logging damage. Advanced reproduction of Douglas-fir was abundant on most of the thinned plots.

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<sup>1</sup>About 32-64 million years ago.

<sup>2</sup>About 12-26 million years ago.

<sup>3</sup>Youngberg, C.T. 1964. Soils of the Black Rock Forest. Unpublished summary. Sch. For., Oreg. State Univ., Corvallis. 1 p.

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<sup>4</sup>Witler, J.W. 1975. The effect of thinning intensity upon understory growth and species composition in an Oregon Coast Range *Pseudotsuga menziesii* stand. M.S. thesis, Oreg. State Univ., Corvallis. 95 p.

# materials and methods

In the fall of 1976, we surveyed the Black Rock Unit to determine density and age of Douglas-fir reproduction beneath three thinning intensities (Table 1). The four replications of the thinning treatments were grouped by elevation, with Replication 1 being the lowest. An open area supporting young Douglas-fir reproduction served as a reference plot.

To adequately represent each plot, we located 20 evenly distributed points on each plot, then

offset a random distance (0.3-2 m) and random direction from each point. There we selected the nearest Douglas-fir tree either having four or more terminal bud scars or standing between 10 cm and 150 cm. The diameter of each sample tree was averaged to the nearest 0.1 mm with a caliper rule. The point of measurement, 1.0 to 1.5 cm above ground, was marked on the stem for later reference. A total of 260 young Douglas-fir was randomly selected and tagged during April, 1977,

Table 1.

## DISTRIBUTION OF UNDERSTORY DOUGLAS-FIR STANDING 1.7 M OR LESS AT BLACK ROCK.

Replications <sup>1</sup>	Dates	Treatment	Understory		
			Density (trees/ha)	Age range (years)	Mean age of sample trees (years)
1	1957,60,65,72	Heavy	3,038	2-11	7
		Medium	793	2-10	8
		Light	673	2-10	7
2	1959-60,65,71	Heavy	1,608	2-13	9
		Medium	865	2-15	9
		Light	380	2-14	8
3	1964,66	Heavy	5,400	2-11	8
		Medium	12,153	2-10	7
		Light	5,400	2-10	7
4	1957,60,62,66,69	Heavy	10,353	2-14	9
		Medium	6,055	2-14	9
		Light	4,848	2-13	8

<sup>1</sup>Plots grouped by elevation so Replication 1 is lowest.



before active growth started. (By the end of active growth, 14 trees had died, reducing the total sample to 246 trees.)

In addition to those 260 trees, we subjectively chose six larger trees apparently of high vigor from each of three heavily thinned plots and one medium thinning so we could emphasize potential growth of Douglas-fir under lower levels of light. At the end of the 1977 growing season, we measured leader growth for that season, as well as total height of the tree.

During the third week of September, 1977, the remaining 246 sample trees were measured for leader growth in 1976 and 1977 (cm), tree height in 1976 (cm), and final diameter (mm). Each tree was clipped at ground level. Needles and stems from the current season were clipped and sealed in a bag labeled "current;" the rest of the aboveground portion of the tree was sealed in another bag labeled "old." All bags were numbered and transferred to the laboratory where the contents were dried for 48 hours at 70°C. Then needles were carefully stripped from stems, and each component was weighed to the nearest 0.1 g to yield the dry weights of new biomass (current needles and stems) and old biomass (needles and stems  $\geq$  1 year) for each tree.

A small basal segment cut from the main stem of each tree before drying was preserved in 20 percent ethanol and later air dried, sanded in cross section, and stained with rhodamine dye. We then counted the annual rings to determine tree age.

For 36 of the stem segments (3 trees randomly selected from each of the 12 thinned plots), we used a micrometer to measure xylem expansion for the last 3 years. Eventually each segment was dried and weighed, then that weight was added to the old biomass of the corresponding tree.

To characterize the understory environments of the three thinning levels and that of the open plot, we:

1. used ozalid paper calibrated against a solarimeter to measure the relative light energy that the crown of each sample tree received over the course of a clear day in mid-July (Friend 1961, Emmingham and Waring 1973). The maximum light energy recorded in the open was assigned a value of 100 percent, and all other light readings were expressed as a percentage of that amount.

2. recorded plant moisture stress or PMS (Waring and Cleary 1967) on three reference trees per plot at 3-week intervals from June 25 to September 8, 1977. PMS was recorded during predawn hours and between noon and 2 p.m. on the day of measurement.
3. read dry and wet bulb temperatures on a sling psychrometer during PMS readings. This information was later converted to estimates of evaporative demand as a function of vapor pressure deficit.
4. continuously monitored air and soil temperatures from May 15 to September 8, 1977 on four 30-day recording thermographs housed in ventilated wooden shelters. One thermograph was placed in the open and one each at the center of a representative plot of the light, medium, and heavy thinnings. The thermographs, calibrated against laboratory instruments, measured air temperature at a height of 1.5 m and soil temperature at a depth of 20 cm.
5. visually estimated vegetative cover around each tree randomly selected for growth analyses. During July, 1977, we laid a metal ring with a 30-cm radius on the ground, centering the sample tree and estimating the area of the circle occupied by woody and herbaceous species.

Analysis of variance was used to detect differences between the thinning intensities in understory environments and average growth of sample trees. We used correlation analysis to examine growth relationships thought to be meaningful; these relationships were inspected graphically (not presented) for each thinning treatment and for replications within the treatments to ensure that patterns were similar. The trees chosen subjectively for their larger size were excluded from these analyses.



# results

## understory environments

Average daily sunlight reaching the crown of understory trees decreased linearly as basal area increased (Fig. 1). Daily sunlight averaged 4.8, 7.8, and 11.5 percent for the light, medium, and heavy thinnings, respectively;

maximum light energy in the open was 528 ly.<sup>5</sup> On all thinned plots, light varied greatly from one tree to the next; coefficient of variation for average light measured at the crown ranged from 40 to 76 percent, and it was greatest on the plots thinned most heavily.

$$51 \text{ langley (ly)} = 0.6976 \text{ kW/m}^2.$$

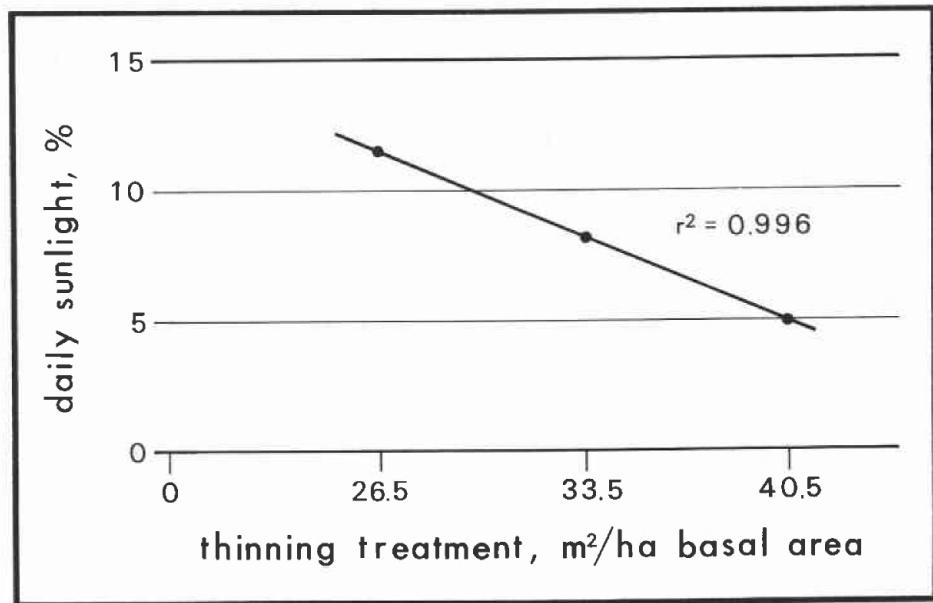


Figure 1.

Relationship between percent of full sunlight received at crown over an entire summer day (averaged for 80 understory seedlings per treatment) and thinning level of overstory (65-year-old Douglas-fir).

Because plant moisture stress did not differ among the thinning treatments, we combined the data for all understory trees (Fig. 2A). Maximum stress in the understory

averaged  $13.2 \times 10^5$  Pa during predawn hours and  $19.6 \times 10^5$  Pa between noon and 2 p.m.<sup>6</sup>. Evaporative demand (Fig. 2B), plotted as a function of vapor

<sup>6</sup> $10^5$  Pascals (Pa) = 1 bar.

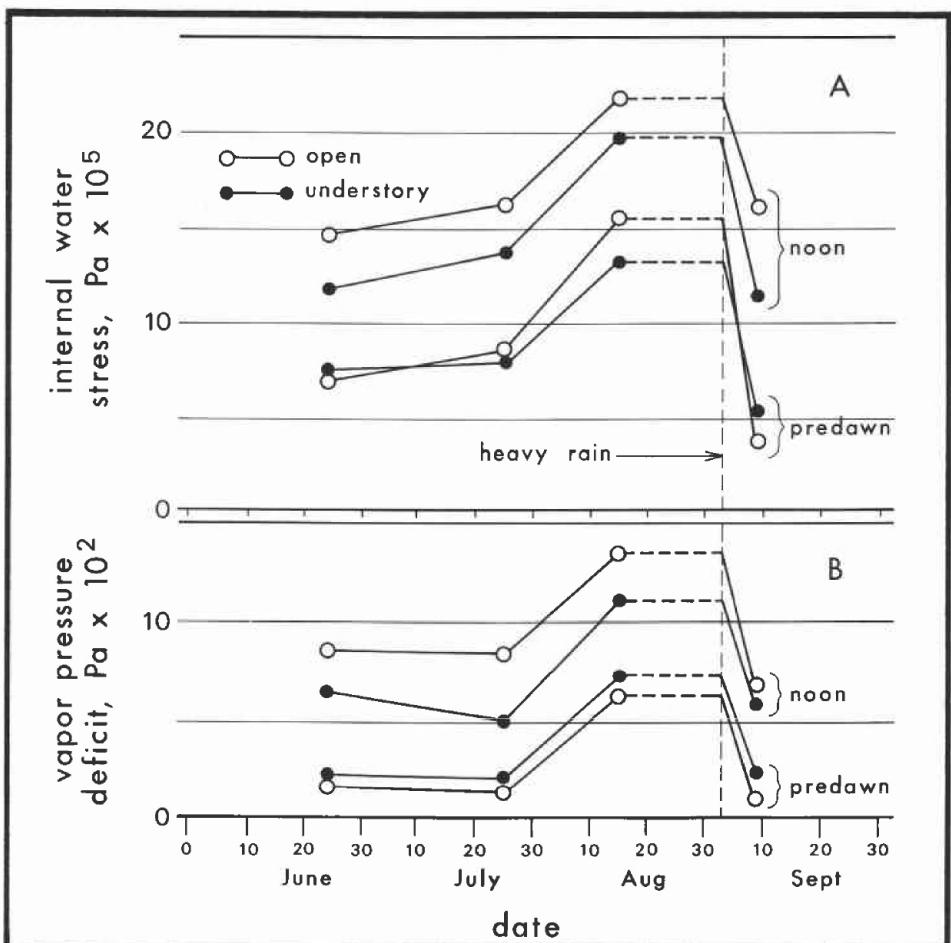


Figure 2.

Water stress and evaporative demand in Douglas-fir reproduction

growing in the understory and in the open.

pressure deficit, closely followed the curves for plant moisture stress and likewise did not differ among treatments.

Although temperature at 1.5 m did not differ among the thinning levels, soil temperature at a depth of 20 cm did, except during August (Table 2). Soil temperature generally increased with thinning intensity as previously reported (Berg 1970).

As thinning intensity increased, so did the proportion of herbaceous to woody plant cover; however, average total vegetative cover

around sample trees did not statistically differ between the thinning levels (Table 3). Although absolute differences in cover of woody and herbaceous species were great, within-plot variation negated any significance, confirming earlier findings by Witler (see footnote 4) and Temmes.<sup>7</sup>

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<sup>7</sup>Temmes, E.K.M. 1978. The quantity and composition of ground vegetation in different light environments under a Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco] stand in the Oregon Coast Range. M.S. thesis, Oreg. State Univ., Corvallis. 49 p.

Table 2.

AIR AND SOIL TEMPERATURES AT BLACK ROCK BENEATH THREE OVERSTORY THINNINGS AND IN THE OPEN.  
(degrees Centigrade)

AIR	Light		Medium		Heavy		Open	
	Diurnal monthly mean	Range <sup>1</sup>	Diurnal monthly mean	Range	Diurnal monthly mean	Range	Diurnal monthly mean	Range
May	8.6.a <sup>2</sup>	10.9-6.3	7.3a	9.9-4.7	7.5a	9.7-5.2	11.3b	15.5-7.1
June	16.6a	20.3-12.9	16.5a	20.8-12.4	17.7a	21.7-13.7	16.2a	22.7-9.6
July	16.3a	20.3-12.4	N/A <sup>3</sup>	N/A	15.3a,b	19.9-10.6	17.9a,c	24.9-10.8
August	20.5a	24.5-16.5	20.2a	24.8-15.5	19.5a	24.2-14.9	22.3a	29.7-14.9
September	15.4a	17.9-12.8	15.2a	18.3-12.1	14.5a	17.2-11.7	16.6b	22.2-10.9
<hr/>								
SOIL								
May	7.4a		N/A		6.3b		9.1c	
June	10.3a		N/A		10.9b		13.0c	
July	12.55a		N/A		13.6b		14.4c	
August	16.5a		N/A		16.4a		16.6a	
September	14.1a		N/A		14.6b		14.4b	

<sup>1</sup>From mean of monthly high to mean of monthly low.

<sup>2</sup>Any two means with different letters are significantly different at P < 0.05.

<sup>3</sup>N/A = not available.

Table 3.

**AVERAGE VEGETIVE COVER IN RELATION TO AVERAGE GROWTH AND BIOMASS PRODUCTION OF UNDERSTORY AND OPEN-GROWN DOUGLAS-FIR.**

Characteristic	Overstory thinning			
	Light	Medium	Heavy	Open-grown
Sample trees	70	79	78	19
Vegetive cover (%)				
Woody	24.64 (23.15) <sup>1</sup>	29.11 (21.67)	15.26 (12.27)	15.00 (14.43)
Herbaceous	7.21 (9.11)	8.23 (10.28)	19.55 (22.20)	63.16 (21.29)
Leader growth (cm)	3.98 (2.51)	5.95 (4.16)	7.38 (4.75)	20.07 (16.79)
Diameter growth (mm)	0.79 (0.34)	1.03 (0.58)	1.25 (0.47)	3.06 (2.13)
New biomass-- needles + stems (g)	0.84 (1.27)	1.79 (2.64)	3.33 (4.08)	31.77 (44.10)

<sup>1</sup>Parenthetical value is one standard deviation.

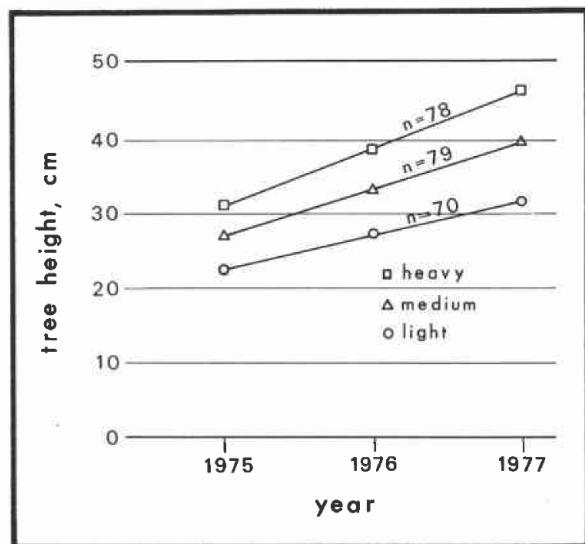
## tree growth in the understory

The age of sample trees ranged from 4 to 15 years. To test differences in average growth and biomass production of understory trees beneath the three intensities of overstory thinning, we conducted an analysis of variance of the form:

Source	Degree of freedom
Replication	3
Treatment	2
Linear	1
Quadratic	1
Replication x Treatment	6
Residual	215

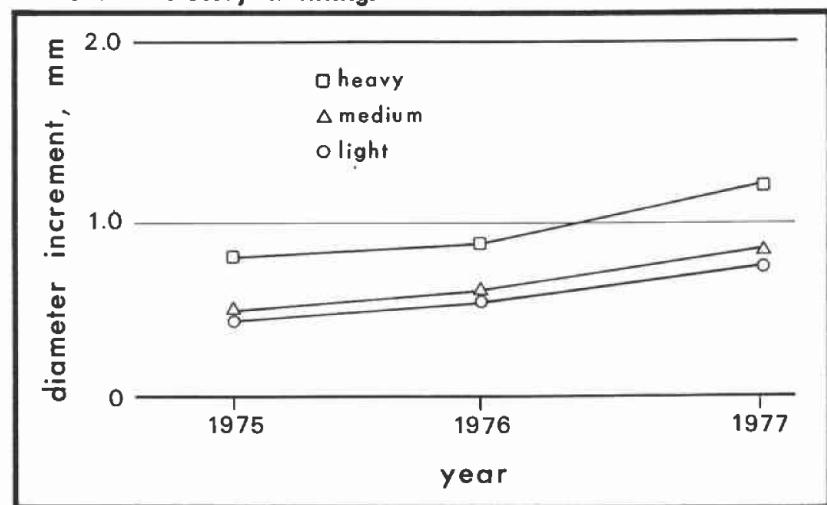
The orthogonal contrasts for the linear and quadratic components were based on equally spaced midpoints of overstory basal areas (26.5, 33.5, and 40.5 m<sup>2</sup>/ha). Among the treatments, linear differences were significant ( $P < 0.05$ ) in leader and diameter growth and in new biomass production.

From 1975 through 1977, differences in average heights of understory trees widened among treatments yet remained evenly spaced (Fig. 3). Concurrently, average rate of xylem growth increased, especially for trees from the heavily thinned plots (Fig. 4).



**Figure 3.**

Average heights of Douglas-fir reproduction growing beneath three levels of overstory thinning.



**Figure 4.**

Diameter increment (inside the bark) for Douglas-fir reproduction

growing beneath three levels of overstory thinning (each point is the average of 12 measurements).

## discussion and

Correlation coefficients were highly significant ( $P < 0.01$ ) for many growth characteristics of understory trees. For example, leader growth in 1977 had correlation coefficients of 0.87, 0.79, and 0.72 with leader growth in 1976, tree height in 1976, and tree height in 1975. Coefficients were 0.68 and 0.69 between diameter growth in 1977 and 1976 measurements for diameter and tree height. New biomass (needles + stems) highly correlated (0.88 and 0.84) with tree height in 1976 and 1975. In contrast, light correlated poorly with leader growth, diameter growth, and new biomass—0.29, 0.36, and 0.36, respectively. Factors such as vegetative competition and non-uniformity in size or age of trees confounded the importance of light on growth and productivity.

On the heavily thinned plots, those understory Douglas-fir chosen subjectively for their larger size averaged 28.6 cm in leader growth and 186 cm in height at 9 years of age; larger trees beneath the medium thinning averaged 26.9 cm in leader growth and 155 cm in height at 7 years.

Of those variables measured to describe the understory environments, light differentiated the thinning levels best. Light reaching the understory varied from one tree to the next, increasing with the degree of thinning. The light thinning approached the open plot in producing a more uniform light environment near the ground. The lack of significant differences in air temperature, plant moisture stress, or evaporative demand among the three understory environments probably resulted from a low radiation load, coupled with air mixing from adjacent treatments.

The strong relationship between leader growth of the current year and leader growth or tree height of previous years, consistent with Emmingham and Waring (1973), indicated that the individual tree closely depicted how light and other factors influence growth and productivity.

Changes in light can affect growth of Douglas-fir (Brix 1970). In our study, light changes of only a few percentage points resulted in significant differences ( $P < 0.05$ ) in mean height, mean diameter growth, and mean production of new biomass by trees under the three thinning levels.

The growth increment of understory trees increased not only with light, but also with size of



# Conclusion

the tree<sup>8</sup>—the same growth pattern, but at reduced rates, as for Douglas-fir on an exposed mesic coastal site (Newton 1964).

From a silvicultural viewpoint, these slower rates of growth offer two advantages. First, the advanced reproduction competes little if any with crop trees in the overstory. Second, a small tree is more flexible, therefore, less susceptible to mechanical damage during overstory removal.

Simple correlation between age and tree height in 1977 was much lower for understory trees ( $r = 0.40$ ) than for open-grown trees ( $r = 0.73$ ), although both coefficients were highly significant ( $P < 0.01$ ). The lower correlation undoubtedly reflected the more varied environment in the understory. Blum (1973) attributed the relatively low correlation between height and age in balsam fir to the species' high tolerance for shade.

This study on the east flank of the Oregon Coast Range has shown that Douglas-fir can establish and grow for at least 15 years when exposed to an average

of only 5 to 12 percent of daily sunlight. These trees were far from static; indeed, patterns of growth—increasing growth increment with tree size—were similar to those of Douglas-fir growing in the open. Growth measured on larger understory trees confirmed the potential of Douglas-fir at low levels of light.

Thinning, in contrast to a shelterwood (Williamson 1973), allowed Douglas-fir to reproduce naturally under the canopy. Although the primary objective in thinning was to increase yield, the future stand of Douglas-fir may have been established in the process.

Our results suggest that a young forest could be established at the time of final harvest, saving several years in regeneration lag time (Starker 1970). Natural regeneration would maintain the option of preserving the local gene pool of the forest (Silen 1976), while averting the costs and failures of planting. Where brush encroaches severely, this reforestation technique may require the control of competing vegetation.

Mechanical damage to understory trees, as a result of overstory removal, must be quantified. Furthermore, morphological and physiological responses to sudden exposure must also be investigated in understory Douglas-fir (Del Rio and Berg 1979, Drew and Ferrell 1977).

<sup>8</sup>Del Rio, Ernest. 1978. Growth behavior of Douglas-fir reproduction in the shade of a managed forest in the interior Coast Range of Oregon. M.S. thesis, Oreg. State Univ., Corvallis. 55 p.

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Del Rio, Ernest and Alan B. Berg. 1979. Growth of Douglas-fir reproduction in the shade of a managed forest. Forest Research Laboratory, Oregon State University, Corvallis. Research Paper 40. 14 p.

On the east side of the Oregon Coast Range, Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco] reproduction established naturally in the understory of a Douglas-fir forest repeatedly thinned to maintain three intensities of basal area.

The amount of daily sunlight reaching the understory best differentiated the three environments. Douglas-fir grew for at least 15 years at an average of only 5 to 12 percent of the daily sunlight. Growth increments increased with light and tree height. Average growth increased linearly as thinning intensity increased. Leader growth and production of new needles and stems highly correlated with leader growth and tree height of previous years.

**KEYWORDS:** *Pseudotsuga menziesii*, natural regeneration, thinning, understory, microenvironment, young-growth.

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# **metric/British conversions**



1 millimeter (mm) = 0.039 inch (in.)

1 centimeter (cm) = 0.39 inch (in.)

1 meter (m) = 3.28 feet (ft)

1 kilometer (km) = 0.62 mile (mi)

1 square meter ( $m^2$ ) = 10.76 square feet ( $ft^2$ )

1 hectare (ha) = 2.47 acres (ac)

1 gram (g) = 0.04 ounces (oz)

Degrees Centigrade ( $^{\circ}\text{C}$ ) = [Degrees Fahrenheit ( $^{\circ}\text{F}$ )-32]/1.8

## **checklist of plants**

### **scientific name**

*Abies balsamea* (L.) Mill  
*Acer macrophyllum* Pursh  
*Pseudotsuga menziesii* (Mirb.) Franco  
*Abies grandis* (Dougl.) Lindl.  
*Holodiscus discolor* (Pursh) Maxim  
*Berberis nervosa* Pursh  
*Cornus nuttallii* Audubon  
*Alnus rubra* Bong.  
*Gaultheria shallon* Pursh  
*Acer circinatum* Pursh  
*Tsuga heterophylla* (Raf.) Sarg.  
*Thuja plicata* Donn.

### **common name**

Balsam fir  
Bigleaf maple  
Douglas-fir  
Grand fir  
Ocean spray  
Oregon grape  
Pacific dogwood  
Red alder  
Salal  
Vine maple  
Western hemlock  
Western redcedar

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