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Six-Year Growth of Douglas-Fir Saplings After Manual or Herbicide Release From Coastal Shrub Competition

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Abstract

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Survival and growth of planted Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) saplings and associated shrubs were observed after seven release treatments had been installed side by side in a large-scale experiment replicated on four areas in the Coast Ranges of Oregon. After 6 years, total height, stem diameter, and crown radius of Douglas-fir were greater in treated areas than in untreated areas. Four times as much Douglas-fir volume as in the control was produced by one manual cutting of competing brush, which also represented the best economic return. Trees subjected to a second and third manual treatment did not grow as much as those with one manual treatment nor did those released with glyphosate or fosamine herbicide or a combination manual plus fosamine treatment. Survival averaged 95.9 percent during the 6-year period.

Six years after treatment, shrub cover was significantly greater around trees in untreated than in treated areas but did not differ significantly in average height. Dominant competitors in untreated areas averaged nearly two-thirds of tree height, those in treated areas only one-third. Effects of herbicide treatment were most visible on red alder (*Alnus rubra* Bong.), salmonberry (*Rubus spectabilis* Pursh), and red elder (*Sambucus callicarpa* Greene). Diversity of competing species temporarily increased after release treatments.

Keywords: Reforestation, Pacific Northwest, Coast Ranges, manual release, herbicide release, Douglas-fir, red alder, seedling survival, seedling growth, glyphosate, fosamine, competing vegetation, salmonberry, thimbleberry, red elder, sword-fern.

Summary

In the highly productive forests of the Pacific Coast Ranges, competition from fast-growing shrubs can reduce the survival and slow the growth of planted Douglas-fir (*Pseudotsuga menziesii* (Mirb) Franco).[1] Overtopping by competitors and concurrent setbacks from animal damage can be major impediments to development of fast-growing, well-stocked stands. Though release effects of some herbicides were well known when the study was started, results achievable with newer selective herbicides and by manual methods were fragmentary, and these release methods had not been compared directly. This cooperative endeavor, initiated in 1980-81 between the Siuslaw National Forest and the Pacific Northwest Research Station, aimed to develop comparable information on seven release alternatives.

The study was conducted as a randomized blocks experiment replicated on four clear-cut areas in the Coast Ranges where well-stocked stands of planted Douglas-fir appeared threatened by fast-growing shrub competition. Six treatments were tested side by side with an untreated control—one, two, or three manual cuttings of shrubs at a 15-centimeter (6-in) height in a 1.2-meter (4-ft) radius around each crop tree with the

[1] Scientific and common names of tree species are from Little (1979); names of other plants are from Hitchcock and Cronquist (1974).

repeat cuts one year apart, aerially spraying with glyphosate[2] or fosamine, and a first-year manual treatment followed a year later by fosamine spraying. Treatments were timed so that their initial effect would occur in the 1981 growing season.

The study areas, each 33 hectares (82 acres) or larger, are located 6 to 14 kilometers (4 to 9 mi) inland and nearly 160 kilometers (100 mi) north to south along the Oregon coast at elevations ranging from 50 to 380 meters (160 to 1,250 ft). Slopes averaged from 35 to 70 percent with primarily west, northwest, and east aspects represented. Surface soils are predominantly sandy loams with low bulk densities—0.47 to 0.94 gram per cubic centimeter. The clearcut and site-prepared areas were well stocked with Douglas-firs planted 2, 3, and 5 years before. Shrub vegetation averaged 195,900 stems per hectare (79,280 per acre) with an average height of 71 centimeters (28 in) at the start of the study.

Before treatment, a grid of 50 sample points 10 meters (33 ft) apart were centrally located within each 2- to 6-hectare (5- to 15-acre) plot. The planted Douglas-fir nearest each grid point was measured for total height and stem diameter at 30 centimeters (12 in) aboveground and remeasured in 1981, 1982, 1983, 1984, and 1986. Twenty nearby shrubs of several species also were marked for observation and remeasurement. Spring and late summer observations of herbicide damage were made on the sample trees and shrubs in the first and second years. Small vegetation cover plots, located at 0.6 and 1.8 meters (2 and 6 ft) from each sample tree were measured yearly from 1980 to 1983. Ocular estimates of shrub cover around each sample tree were made in 1984 and 1986.

In the first 6 years after release, only 4 percent of the sample trees died. About one-fourth of the mortality was attributable to the herbicide or manual treatments. Scattered mortality occurred on all areas and in every treatment; in the first 2 years, it was greatest among the youngest trees.

Six years after initial measurement and release, Douglas-firs averaged four times as tall and nearly seven times as large in stem diameter at 30 centimeters (12 in). In both total height and stem diameter, trees not released were significantly smaller than those given release—462 vs 578 centimeters (182 vs 228 in) for total height, 71 vs 107 millimeters (2.8 vs 4.2 in) for stem diameter. Average height and stem diameter of trees released manually were somewhat greater than for those released by herbicide. Two or three manual release treatments were no better than one, and growth differences among herbicide treatments were minor. Site quality effects on tree growth became evident as indicated by changed rankings among locations for average total height and stem diameter.

Four times as much stem volume as in the control was produced by one manual cutting of competing brush, which also represented the best economic return among release treatments (fig. 1). One manual cutting plus spraying with fosamine produced the least result among release treatments, a 32-percent greater economic return than no release. Size differences also were evident in crown width; the horizontal spread of the longest limbs averaged 301 centimeters (119 in) for released trees and 227 centimeters (89 in) for trees not released.

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[2] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

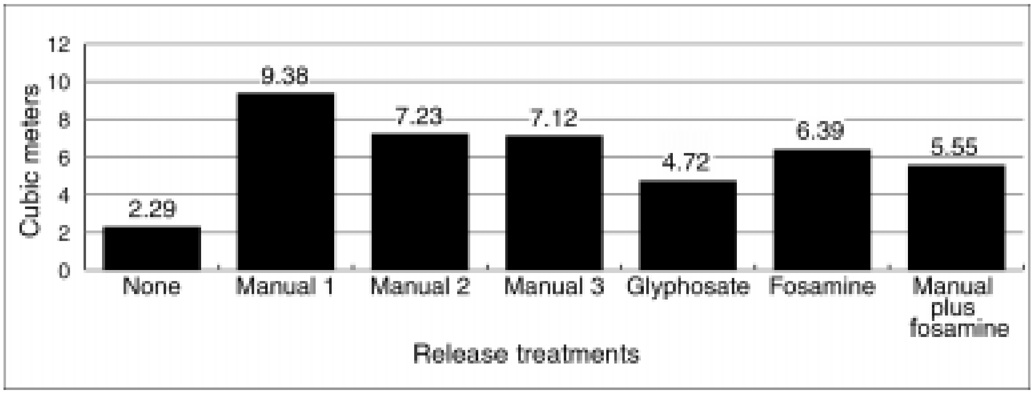

Figure 1—Stem volume per acre 6 years after each release treatment.

When the study started, the shrub cover averaged more than half as tall as the Douglas-fir saplings: range, 45 to 75 percent. In 1983, after all treatment regimes had been applied, shrub canopy in the untreated plots averaged one-third of tree height but only 11 percent of tree height where three manual treatments had been applied. By 1986, dominant competitors around sample trees averaged nearly two-thirds of tree height in untreated areas and one-third of tree height in treated areas. Relative to Douglas-fir, height of salmonberry (*Rubus spectabilis* Pursh) decreased in all treatments from 1984 to 1986; relative heights of red alder (*Alnus rubra* Bong.), vine maple (*Acer circinatum* Pursh), and red elder (*Sambucus callicarpa* Greene) increased in some treatments and decreased in others.

Diversity among competing vegetation was not reduced by any of the release treatments; in fact, slight gains in diversity might be attributed to some treatments. After 6 years, only 10 to 15 species per treatment were represented among dominant competitors of the Douglas-fir trees. Salmonberry was the most frequent competing dominant in every treatment (range, 28 to 49 percent).

The growth and development of Douglas-fir saplings was definitely speeded by reducing competition from associated vegetation. But even in the untreated control, most Douglas-firs overtopped associated shrubs during the 6-year study period. Some trees, especially in one untreated control, are still vunerable to severe overtopping by red alder, however.

Greater understanding of vegetation dynamics must be gained to better identify which stands of Douglas-fir critically need release to survive, which can benefit substantially from release, and the ones in which competing vegetation is no serious threat. In several studies, competition from associated vegetation has not been as limiting as anticipated. Also, when competing hardwoods are components of the competition, an early release treatment may not be sufficient. Followup tending may be necessary several years later to prevent severe overtopping of Douglas-fir by fast-growing hardwoods.

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Introduction

In the highly productive forests of the Pacific Coast Ranges, unrestrained competition from salmonberry (*Rubus spectabilis* Pursh), thimbleberry (*Rubus parviflorus* Nutt.), red alder (*Alnus rubra* Bong.), and associated species may reduce the survival and slow the growth of planted Douglas-firs (*Pseudotsuga menziesii* (Mirb.) Franco). Overtopping by competitors and concurrent setbacks from animal damage can be major impediments to development of fast-growing, well-stocked Douglas-fir stands. Herbicides to reduce vegetative competition were developed in coastal forests and have been used for many years. Results achievable with newer selective herbicides and by manual release were fragmentary, however, and these release methods had not been compared directly.

In this study, seven release options were compared side by side in a replicated, large-scale experiment. The four study sites represented strongly competitive reforestation conditions where salmonberry, thimbleberry, elder (*Sambucus* L. spp.), and other tall woody species were plentiful and threatened to overtop Douglas-firs planted in clearcuts. Information obtained on the postrelease survival and growth of Douglas-fir saplings plus effects on competing vegetation are presented in this paper.

The study was a cooperative endeavor by the Siuslaw National Forest and the Pacific Northwest Research Station of the U.S. Department of Agriculture, Forest Service. Its impetus was a nationwide effort by the Forest Service to compare herbicide and manual release methods in major forest types.

Methods

Different methods of releasing planted Douglas-firs from competing salmonberry and associated vegetation were compared side by side on four areas located within the Siuslaw National Forest in the Coast Ranges of Oregon. The comparisons were made on an operational scale by using entire clearcuts or portions of extra large ones as replications.

Answers were sought to these four questions:

- Do any of the release treatments improve the survival and growth of the planted Douglas-firs?
- What is the relative effectiveness of manual and herbicide release methods on the survival and growth of the planted Douglas-firs?
- Are two or three successive manual release treatments more effective than a single treatment?
- Is a combined manual and herbicide release treatment more effective than others?

Area Descriptions

The study areas, each 33 hectares (82 acres) or larger, are located 6 to 14 kilometers (4 to 9 mi) inland from the Oregon Coast in the geographic territory bounded by longitude 123° 53' to 124° 3' W. and latitude 43° 55' to 45° 15' N. (table 1). All four are located on the Siuslaw National Forest at elevations ranging from 50 to 380 meters (160 to 1,250 ft). Average slopes of the areas range from 35 to 70 percent, and dominant aspects represented include west, northwest, and east (fig. 2). All have minor ridges and draws providing short slopes of other aspects.

Table 1—Description of the study areas in the Siuslaw National Forest

Characteristic	Study area			
	Farmer Roundtop	Howell Ridge	Bailey	Popo Maple
Location:				
Longitude	123° 53’ W.	123° 55’ W.	124° 3’ W.	123° 59’ W.
Latitude	45° 15’ N.	44° 20’ N.	44° 5’ N.	43° 55’ N.
Distance inland (kilometers)	6	14	6	14
District	Hebo	Waldport	Mapleton	Mapleton
Township	T. 4 S.	T. 14 S.	T. 17 S.	T. 19 S.
Range	R. 10 W.	R. 10 W.	R. 11 W.	R. 11 W.
Section	2, 3	20, 29	17, 18	23
Site:				
Size (hectares)	49	96	36	33
Elevation (meters)	120-245	275-380	50-145	170-245
Aspect (degrees)	270	294	280	90
Slope in plots (percent):				
Average	35	66	61	70
Range	25-40	55-80	42-80	50-90
Vegetation type	Alder-salmonberry	Alder-salmonberry	Alder-salmonberry	Alder-salmonberry-vine maple
Big-game damage	Moderate	Moderate	Heavy	Light

Figure 2—Appearance of the Farmer Roundtop study area in June 1983 soon after the third manual release treatment. Elevations range from 120 to 245 meters, aspect is west, and slopes range from 25 to 40 percent.

In 1980, woody vegetation averaged 195,900 stems per hectare (79,280 stems per acre or 1.82/ft^2), with an average diameter of 1.12 centimeters (0.4 in) and an average height of 70.9 centimeters (28 in). The stems per square meter ranged from 15.6 at Popo Maple to 24.9 at Farmer Roundtop (1.45 to 2.31/ft^2). Average stem diameters ranged from 1.02 to 1.22 centimeters (0.4 to 0.5 in) and average shrub height from 44 at Bailey to 100 centimeters at Popo Maple (17 to 39 in).

Sandy loam was the predominant texture for soil samples taken from the top 30 centimeters (12 in) in each study area, with only 4 loams and 1 silt loam among the 30 samples (table 2). Total soil bulk density was low; the averages ranged from 0.67 to 0.75 gram per cubic centimeter with individual samples ranging from 0.47 to 0.94. Soil particles greater than 4.75 millimeters (0.19 in) in diameter constituted 5.9 to 15.4 percent of the total weight per sample, oven-dry basis.

Study Design and Techniques

The study was a randomized blocks experiment having four replications (areas) and seven release treatments on each area. Wide geographic representation, the same vegetation type, reasonable uniformity of aspect and cover, and apparent need for release of a moderate- to well-stocked Douglas-fir plantation were the chief criteria followed in selecting study areas.

Each area was subdivided along topographic and other features into seven plots ranging from about 2 to 6 hectares (4 to 15 acres) in size. Ease of treatment application and boundary marking were key considerations in layout of plots. Common boundaries between plots were marked with highly visible markers. Plots were mapped carefully so that the acreage of each could be accurately determined to contract release treatments and calculate spray volumes.

Table 2—Soil characteristics in the study areas

	Study area			
Characteristic	Farmer Roundtop	Howell Ridge	Bailey	Popo Maple
Published information:				
Soil series	Salander/Winema	Preacher/Bohannon	Preacher/Bohannon	Preacher/Bohannon
Taxonomy	Typic Dystrandepts	Andic Haplumbrepts	Andic Haplumbrepts	Andic Haplumbrepts
Parent material	Colluvium Sandstone and shale	Arkosic sandstone Sandstone	Arkosic sandstone Sandstone	Arkosic sandstone Sandstone
Soil texture	Silt loam	Gravelly loam Clay loam	Gravelly loam Clay loam	Gravelly loam Clay loam
Water-holding capacity	Deep, well-drained	Moderate to deep, well-drained	Moderate to deep, well-drained	Moderate to deep, well-drained
Site specific:				
Samples (number)	6	6	9	9
Texture—				
Modal	Loam	Sandy loam	Sandy loam	Sandy loam
Range	Silt loam - sandy loam	Sandy loam	Loam - sandy loam	Sandy loam
Sand (percent)	53.0	59.8	59.8	60.3
Silt (percent)	35.8	28.2	27.0	24.8
Clay (percent)	11.2	12.0	13.2	14.9
Total soil bulk density				
Average (gram/cubic centimeter)	0.67	0.70	0.72	0.75
Range	0.47 - 0.87	0.53 - 0.87	0.53 - 0.94	0.62 - 0.87
Size fractions (percent)—				
< 2 mm	83.26	86.08	76.34	73.50
2-4.75	8.44	7.98	8.27	13.49
>4.75	8.30	5.94	15.39	13.01

Immediately after plot layout, a grid of 50 sample points was centrally located on 0.5 hectare (1.25 acres) within each plot. Grid points were located 10 meters (33 ft) apart with 5 rows of 10 points (or equivalent) within each grid. These sample points were marked with long, painted cedar stakes and numbered consecutively from plots one through seven in each area.

Field measurements—To determine the effects of release on survival and growth of planted Douglas-firs, 50 trees were designated for repeated measurements on every plot. The planted Douglas-fir found nearest each point in the grid was tagged and flagged as a sample tree. After all sample trees had been identified, one of the seven release treatments was assigned randomly to the seven plots on each area.

Total tree height in 1979 and 1980 was determined during the initial measurement after the 1980 growing season, and heights were remeasured in 1981, 1982, 1983, 1984, and 1986. Stem diameters at 30 centimeters (12 in) above ground level were first measured after the 1980 growing season and again in 1983, 1984, and 1986. Diameters also were measured at breast height in 1986. Maximum width of crown and its distance aboveground were measured in 1984 and 1986. All measurements were made in metric units.

Damage to sample trees caused by manual release, animals, spray drift, or other sources was recorded systematically when trees were remeasured. Separate examinations were made in herbicide-treated plots in spring and late summer of the first and second seasons after spraying to rate the visible effect on trees. Defoliation and top kill were rated as a percentage of the total crown.

The visible effects of herbicide treatments on the most common shrub species also were observed in spring and late summer examinations the first and second year after spraying. Damage was rated for the 20 plants of each shrub species whose crowns were intercepted by line transects located between grid points on each sprayed plot. Sample plants of the same species had to be at least 2 meters (6.6 ft) apart. Damage was rated on a numerical scale from no damage (0) to complete kill (7).

Shrub density was determined near each sample tree. Stems were counted and their diameters measured after the 1980 growing season and again after the 1983 season. Shrub heights were measured on the same plots after the 1980, 1981, 1982, and 1983 growing seasons. Shrubs were sampled on square 0.09 meter plots (1 ft^2), one located 0.6 meter (2 ft) away from and the other 1.8 meters (6 ft) away from each sample tree. These plots were located along transect lines that defined the route of travel between sample trees. In 1984 and 1986, an ocular estimate was made of total vegetation cover on a 16.2 square-meter (4-milacre) circular plot with each sample tree as the center-point. A second ocular estimate of cover at each tree reflected the observer’s judgment of how much cover was directly impinging on tree development.

Descriptive information was obtained about each study area from available records and some field sampling. Soil texture and bulk density were determined in three samples from each of the main slopes on each study area by using the bead-cone technique to measure soil volumes removed (Flint 1983) and the hydrometer method for texture analysis (Day 1965).

Summaries and analyses—Tree survival, total height and height increment, stem diameter and diameter increment, diameter at breast height (d.b.h), and crown size data were summed to obtain means with standard errors and minimum and maximum values by area, treatment, and examination date. The basic sample for which a mean was calculated comprised all 50 trees or the survivors observed on a plot.

Tree growth data were subjected to analysis of variance for a randomized blocks design. Initial tree height, prerelease height growth, and initial stem diameter were tested as covariates in separate sets of analyses but did not improve or clarify comparisons; thus, results of covariate analyses are not reported. Probability values as determined by *F*-test are provided as appropriate. Duncan’s multiple range test (Duncan 1955) was used to identify significant differences among ranked means at the 1- and 5-percent probability levels. Orthogonal contrast comparisons also were made for selected treatment groupings. Survival data were not subjected to analysis of variance; the low and scattered mortality precluded any meaningful statistical comparisons.

Stem volume produced by the average tree in 6 years after each method of release was calculated as a conical form with the average diameter at 30 centimeters (12 in) aboveground as the width of the base and the average total height as the length of the cone. Volume per acre (metric) was determined by multiplying the average volume per tree by the number of surviving trees per acre, obtained by reducing a defined full stocking of 400 trees per acre by the survival percentage resulting from each method of release.

Data for shrub density and height in the 1980-to-1983 period were summarized by treatment and area. Densities and heights at 0.6 and 1.8 meters (2 and 6 ft) from sample trees were compared statistically by analysis of variance and Duncan's (1955) test for effect of treatment, particularly the manual treatments. The 1984 and 1986 vegetation data also were summarized and compared to determine total cover and impinging cover by treatment. Average heights were calculated for competing species that were the main and second most important competitor on plots.

Release Treatments

Seven release options were compared side by side on each study area. The options tested included:

- **No release.** The trees and vegetation received no treatment.
- **Manual 1 year.** Brush was cut by chainsaw within 15 centimeters (6 in) of ground level in a 1.2-meter (4-ft) radius around each selected tree. Crowns of any shrubs encroaching into this radius around the tree also were cut. The first treatment of all plots receiving manual release was done in May to July 1981 (table 3).
- **Manual 2 years.** The initial manual release cutting as described above was followed about a year later by a second cutting done in the same manner. The second treatment of all plots designated for two or three manual cuttings was applied in July or August 1982.
- **Manual 3 years.** The first two cuttings as described above were followed by a similar third effort in May, June, or July 1983 on the four plots designated for three manual release treatments.
- **Glyphosate.** Designated plots were aerially sprayed with glyphosate (N-[phosphonomethyl] glycine) in September 1980 at the rate of 0.45 kilogram per hectare (1 lb per acre) acid equivalent in water without adjuvants, applied at the rate of 94 liters of mix per hectare (10 gal per acre). (Registration for conifer release in western Oregon: EPA 524-308-AA; SLN-OR-770055; trade name—Roundup® [Monsanto].)
- **Fosamine.** Designated plots were aerially sprayed with fosamine (ammonium ethyl carbamoylphosphonate) in September 1980 at the rate of 1.36 kilograms per hectare (3 lb per acre) acid equivalent in water, applied without adjuvants at the rate of 94 liters of mix per hectare (10 gal per acre). (Registration for conifer release in western Oregon: EPA 352-376-AA; SLN-OR-770054; trade name—Krenite® [DuPont].)
- **Manual plus fosamine.** Manual release was applied once in May, June, or July 1981 as described above for the manual 1-year treatment. The supplemental chemical treatment was applied aerially in September 1981, with the same formulation as used previously in the fosamine treatment.

Table 3—Treatment history of the study areas

Treatment	Study area: Farmer Roundtop	Howell Ridge	Bailey	Popo Maple
Harvested (year)	1977	1977	2-77	6-75
Site preparation and date	None	Sprayed Tordon 101, 5-78 Broadcast burned 78	Broadcast burned 7-77	Broadcast burned 8-75
Postburn treatment	—	—	Grass seeded 11-78	—
Planting:				
Date	4-78	3-79	3-78	2-76
Spacing (meters)	2.4x2.4	2.7x2.7	2.7x2.7	3.0x3.0
Stock type	2-1	2-0	2-0 + plugs	2-1
Tubed	Yes	Yes, 13x13	—	—
Trapped	8-78	—	—	—
Release:				
None	—	—	—	—
1 manual cutting	5-81	7-81	6-81	6-81
2 manual cuttings	5-81, 7-82	7-81, 8-82	6-81, 7-82	6-81, 7-82
3 manual cuttings	5-81, 7-82, 5-83	7-81, 8-82, 6-83	6-81, 7-82, 7-83	6-81, 7-82, 7-83
Glyphosate (aerial)	9-80	9-80	9-80	9-80
Fosamine (aerial)	9-80	9-80	9-80	9-80
Manual plus fosamine (aerial)	5-81, 9-81	7-81, 9-81	6-81, 9-81	6-81, 9-81

The goal of manual treatments was to release up to 1,075 well-distributed, planted Douglas-firs per hectare (435 per acre). Thus, trees were released to achieve approximately a 3- by 3-meter (10- by 10-ft) spacing. With a clearing radius of 1.2 meter (4 ft) around each released tree, about 50 percent of the plot area was manually cut.

Herbicides were applied by helicopter, with half the volume applied in each of two flights, one at right angles to the other. A boom spray system was used with disc-type teejet nozzles, D-8 orifice tips, no spinners, and an operating pressure between 1.7 and 2.4 bars. Flight speeds were under 97 kilometers per hour (60 mi per hr), and wherever possible, at heights of 21 meters (70 ft) or less above the vegetation cover. Suitable weather conditions prevailed during spraying: temperature less than 21 °C (70 °F), relative humidity over 50 percent, and wind velocity less than 10 kilometers (6 mi) per hour.

Herbicide and manual applications were timed so that the first effects of release in all treatments would occur in the 1981 growing season.

Application of release treatments was the responsibility of individual Ranger Districts in the Siuslaw National Forest. The Districts collaborated on Forest-wide spraying contracts so that the same contractor and pilot applied the two sprays on plots in all four areas in 1980. Likewise in 1981, a single contractor applied the spray in all four areas. Contracts for manual release were awarded and supervised by individual Districts. The Forest-wide spray contract as well as efforts directed by individual Districts represented operational methods in use at the time.

Results

The effects of release were determined in several ways: (1) observation of visible effects on trees and shrubs after herbicide treatment; (2) tree survival, height and diameter growth, and crown form after all release treatments; and (3) changes in density, composition, and height of shrub competition after release treatment.

Visible Effects of Herbicides

Trees and shrubs subjected to aerial spraying in September were subsequently examined four times for visible damage, in late spring and late summer of the first and second growing seasons. Defoliation and top kill on trees were rated separately as a percentage of crown affected. Herbicide effects on shrubs were rated from 0 to 7 on a numerical index:

Number	Description
0	No effect
1	Spastic effects or deformed foliage, or both
2	Less than half of aerial parts killed, many green leaves
3	50 percent or more top kill, many green leaves
4	No top kill but severe defoliation, feathering, etc.
5	Less than 50 percent top kill, few or no green leaves
6	More than half of aerial parts killed, few or no green leaves
7	Shrub dead

The damage data have been summed and averaged to show the relative degree of damage by treatment.

On Douglas-fir—All three herbicide treatments caused some defoliation, top kill, and a scattering of mortality. Defoliation from fosamine was about half as much as in the manual plus fosamine and glyphosate treatments—1.46 versus 2.84 and 2.93 percent, respectively, expressed as average amount of defoliation for all Douglas-firs exposed (table 4). Damage was variable; many trees were not visibly damaged, but a few were severely damaged (fig. 3).

In terms of frequency of occurrence, 6.3 percent of all trees in herbicide treatments had top kill; 12.8 percent had defoliation. Top kill and defoliation frequency ranged from 0 at Popo Maple to 14.7 and 40.0 percent, respectively, at Farmer Roundtop. By treatment, top kill and defoliation frequency was 2.0 and 10.0, 2.5 and 7.0, and 14.5 and 21.5 percent, respectively, for fosamine, manual plus fosamine, and glyphosate. None of the trees at Popo Maple was affected by herbicide, and only those treated with glyphosate were affected at Bailey. At Farmer Roundtop and Howell Ridge, some trees in all three herbicide treatments showed visible damage.

Eight Douglas-firs apparently died from herbicide effects. Three of these died during the two seasons when damage observations were made: the others, 1 year or more later (table 23). Four trees died from herbicide-related effects in the manual plus fosamine treatment, three after glyphosate treatment, including two in the manual 2 treatment that were exposed to glyphosate drift. Six trees died from spray at Farmer Roundtop, one at Howell Ridge, and one at Bailey.

Table 4—Visible damage to Douglas-firs after each herbicide treatment

Area and examination	Glyphosate			Fosamine			Manual plus fosamine		
	Trees alive	Top kill	Defoliation	Trees alive	Top kill	Defoliation	Trees alive	Top kill	Defoliation
	Number	*Percent*[a]	*Percent*	*Number*	*Percent*	*Percent*	*Number*	*Percent*	*Percent*
Farmer Roundtop:									
1st year, spring	50	2.0	3.4	50	0.1	0.1	50	0	2.0
1st year, summer	50	2.2	6.6	50	.2	3.6	49	2.0	4.3
2d year, spring	50	2.2	7.8	50	.4	3.8	49	3.6	8.6
2d year, summer	50	2.3	7.9	50	.4	3.8	49	3.6	9.1
Howell Ridge:									
1st year, spring	50	.2	.2	50	0	0	46	2.3	2.3
1st year, summer	50	.2	.2	49	2.0	2.0	45	2.3	2.3
2d year, spring	50	.2	.2	48	2.1	2.1	45	2.3	2.3
2d year, summer	50	.2	.2	48	2.1	2.1	45	2.3	2.3
Bailey:									
1st year, spring	50	.6	.6	50	0	0	50	0	0
1st year, summer	50	1.1	1.4	50	0	0	50	0	0
2d year, spring	49	1.3	3.2	50	0	0	50	0	0
2d year, summer	49	1.8	3.6	50	0	0	50	0	0
Popo Maple:									
1st year, spring	50	0	0	50	0	0	50	0	0
1st, year, summer	50	0	0	50	0	0	50	0	0
2d year, spring	50	0	0	50	0	0	50	0	0
2d year, summer	50	0	0	50	0	0	50	0	0
Total or average									
1st year, spring	200	.70	1.05	200	.03	.03	196	.54	1.05
1st year, summer	200	.88	2.05	199	.55	1.41	194	1.06	1.62
2d year, spring	199	.93	2.80	198	.61	1.46	194	1.44	2.71
2d year, summer	199	1.06	2.93	198	.61	1.46	194	1.44	2.84

[a] Percent damage for individual trees summed and divided by total number of trees observed.

On competing species—The visible effects of herbicide treatment on species associated with the Douglas-fir ranged from zero to severe (table 5). For given species, the damage also differed by treatment, area, and examination date. Data for all four examination dates are shown because some species showed increased damage over time, some showed about the same, and others showed less damage due to either recovery or disappearance of damaged leaves and stems. Index averages for areas combined are listed in table 5; tables 20, 21, and 22 show number of samples and index values by treatment, area, species, and examination.

Figure 3—Defoliation occurred on about 9 percent of Douglas-firs sprayed with fosamine (Farmer Roundtop, manual plus fosamine treatment, June 1983).

Glyphosate had the greatest overall effect on the vegetation complex, and its effect was still evident by late spring of the third growing season (fig. 4). Averages developed by summing damage index values for all species represented at each examination (table 5) show these differences:

Treatment	First spring	First summer	Second spring	Second summer
		Examination		
Glyphosate	2.86	2.16	1.66	1.69
Fosamine	1.57	1.96	1.12	1.52
Manual plus fosamine	1.33	1.28	1.29	1.32

Fosamine treatment seems to have been slightly more effective (damaging) when used in 1980 rather than in 1981 when the vegetation was a year older. The effects of fosamine appeared to decrease less rapidly over time than those for glyphosate.

Table 5—Visible damage to associated species after each herbicide treatment

Treatment and species	Examination			
	First spring	First summer	Second spring	Second summer
	Damage index[a]			
Glyphosate:				
Salmonberry	4.52	4.64	3.90	5.23
Thimbleberry	4.13	4.50	3.78	3.55
Vine maple	.98	.53	.90	.60
Red alder	4.38	4.24	4.09	4.09
Red elder	3.46	3.98	3.40	3.24
Sword-fern	1.83	2.40	1.29	1.36
Red huckleberry	1.04	.90	1.07	.94
Salal	*	0	0	0
Bracken	6.65	1.00	1.00	1.00
Ocean-spray	1.60	1.60	.44	.30
Evergreen huckleberry	0	0	0	0
Chaparral-broom	*	*	0	0
Average	2.86	2.16	1.66	1.69
Fosamine:				
Salmonberry	3.76	3.20	2.48	2.51
Thimbleberry	1.16	1.63	.74	.79
Vine maple	2.67	5.00	3.30	2.90
Red alder	3.93	4.28	4.08	3.95
Red elder	1.81	2.61	1.78	2.42
Sword-fern	.26	1.38	.03	.09
Red huckleberry	.90	1.15	.32	.36
Salal	0	0	0	0
Bracken	1.00	.50	*	*
Ocean-spray	1.83	1.83	.67	.67
Willow spp.	0	0	0	*
Evergreen huckleberry	*	*	0	*
Chaparral-broom	*	*	0	*
Average	1.57	1.96	1.12	1.52

Table 5—Visible damage to associated species after each herbicide treatment (continued)

Treatment and species	Examination: First spring	First summer	Second spring	Second summer
	Damage index[a]			
Manual plus fosamine:				
Salmonberry	2.83	2.56	1.89	2.15
Thimbleberry	.75	.98	.78	.73
Vine maple	3.00	2.45	2.50	2.55
Red alder	4.37	4.07	5.19	4.98
Red elder	1.59	1.91	1.60	1.86
Sword-fern	0	0	0	0
Red huckleberry	.75	.80	.75	.90
Salal	0	0	0	0
Evergreen huckleberry	0	0	.15	0
Chaparral-broom	0	0	0	0
Average	1.33	1.28	1.29	1.32

* = No observation.

[a] Averaged values based on an index from 0 for no effect to 7 for complete kill observed on designated sample shrubs.

Figure 4—In the third growing season, there was a marked contrast in the presence and appearance of associated species after herbicide or manual release: view of glyphosate (left) and 2-year manual treatment (right) at Farmer Roundtop in June 1983.

Visible damage from spraying with glyphosate differed substantially by area. It was highest at Farmer Roundtop and Bailey, intermediate at Howell Ridge, and lowest at Popo Maple (4.75, 4.24, 2.56, and 1.64, respectively) based on composite indices for the different number of species observed at each area (table 20). The same ranking prevailed (4.92, 4.32, 3.08, and 2.57) based on composite indices for the three species common to all areas (salmonberry, red elder, sword-fern), but rankings of individual species differed. Damage to salmonberry was high and similar for all areas except Howell Ridge. Damage to red elder (*Sambucus callicarpa* Greene) ranked from high to low for Bailey, Farmer Roundtop, Howell Ridge, Popo Maple, respectively. For sword-fern (*Polystichum munitum* (Kaulf.) Presl), there was wide disparity in effect from 5.40 at Farmer Roundtop to 0.05 at Popo Maple. Three species—salal (*Gaultheria shallon* Pursh), evergreen huckleberry (*Vaccinium ovatum* Pursh), and chaparral-broom (*Baccharis pilularis* DC.)—showed no signs of damage, and three others—vine maple (*Acer circinatum* Pursh), red huckleberry (*V. parvifolium* Smith), and ocean-spray (*Holodiscus discolor* (Pursh) Maxim.)—never had a damage index as high as 2.

Visible damage from spraying with fosamine also differed substantially by area. The effects again were greatest at Farmer Roundtop and least at Popo Maple compared as composite indices (range, 3.45 to 1.34) for the different number of species observed at each area (table 21). Among indices for the three species common to all areas, fosamine effects were greatest at Farmer Roundtop and those at Popo Maple and Howell Ridge equally low. Four species—salal, evergreen huckleberry, willow (*Salix* sp.), and chaparral-broom—showed no visual damage from aerial spraying with fosamine, and three others—bracken (*Pteridium aquilinum* (L.) Kuhn.), ocean-spray, and red huckleberry—never had a damage index as high as 2.

Visible damage to competing species resulting from spraying fosamine a year after manual release differed from that in the fosamine treatment. The damage indices were lower, and they ranked differently by location: 2.37, 1.88, 1.19, and 0.75, respectively, for Howell Ridge, Farmer Roundtop, Popo Maple, and Bailey (table 22). The composite indices for the three common species also show the most damage at Howell Ridge and the least at Bailey. In the manual-plus-fosamine treatment, three species—salal, sword-fern, and chaparral-broom—showed no damage at any examination, and three others—thimbleberry, evergreen huckleberry, and red huckleberry—never had a damage index as high as 2.

Tree Development

The effects of release treatments on tree development are presented in terms of survival, growth in height, diameter, and crown width, and the comparative reduction in density and height of competing species.

Survival—Survival of Douglas-fir was high during the 6-year period of observation: 95.9 percent. A total of 58 died from all causes: 18, 19, 13, and 8, respectively, on Farmer Roundtop, Howell Ridge, Bailey, and Popo Maple. Highest mortality during the first 2 years of the study occurred at Howell Ridge (14 of 24) where the Douglas-firs were a year younger than elsewhere. Mortality during the rest of the study was well scattered among areas and years (table 23).

Some trees died in every release treatment, ranging from 4 in the fosamine and manual 3 treatments to 13 in the manual 2 and manual-plus-fosamine treatments. Death of eight trees was attributed to herbicide treatment, six others to being cut during manual release, and the rest to a variety of causes:

Treatment	Cut by mountain beaver	Cut by saw	Other mechanical	Spray	Browse	Unknown	All
None	8	0	0	0	0	3	11
Manual 1	0	1	1	0	0	5	7
Manual 2	2	3	3	2	1	2	13
Manual 3	1	0	0	0	0	3	4
Glyphosate	1	0	1	1	0	3	6
Fosamine	2	0	1	1	0	0	4
Manual plus fosamine	4	2	0	4	0	3	13
Total	18	6	6	8	1	19	58

Toppling caused by snow or J-root planting are included in the “other mechanical” category. Several trees included in the “unknown” column probably died from root rot, as evidenced by some defoliation and color changes before death.

Statistical tests of differences in survival among treatments were not made because mortality was low and no trend was evident.

Height—Sample trees were measured in early 1981 to ascertain their total height in both 1979 and 1980 and their annual height increment immediately before treatment. The total height in 1980 is the base level from which changes due to treatment were determined. Because of lag time in both treatment effect and tree response, few differences should be expected in 1981 and full differences not until after 1983, following application of the third manual release treatment.

In the 6 years after initiation of treatment, average total height of Douglas-fir increased more than fourfold, from 125 to 562 centimeters (table 24). The gain in average growth differed greatly by area, with an increase of 6.87, 6.33, 3.70, and 3.37 times the 1980 height, respectively, at Howell Ridge, Bailey, Farmer Roundtop, and Popo Maple. Despite the lowest rate of height increase, the largest numerical increase in height was at Popo Maple and the least at Farmer Roundtop (507 vs 337 centimeters).

Average height of study trees differed among areas at the start of the study and also 6 years later. The tallest as well as oldest trees averaged 721 centimeters (Popo Maple, 3 years in nursery, 11 on site). At Howell Ridge, the youngest (2 years in nursery, 8 on site) and initially shortest trees averaged taller after 6 years than those at Farmer Roundtop (495 vs 462 centimeters) that in 1980 were half a meter taller (72 vs 125 centimeters). Also, height of trees at Bailey that were initially shorter were taller on average after 6 years than those a year older (total age) at Farmer Roundtop.

Average tree height differed among treatments in 1980 and at every examination afterward (fig. 5, table 24). Analysis of variance tests of differences among means indicated that average height did not differ significantly among treatments in 1980, but 6 years later differences were detectable ($P = 0.091$). The statistical probability that differences exist has increased steadily from 1980 onward (table 6).

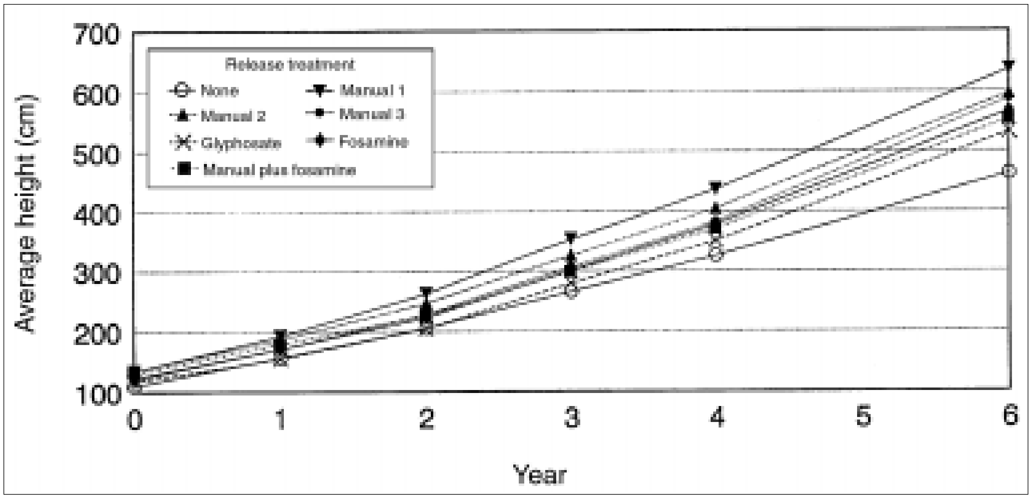

Figure 5—Average total height attained by Douglas-firs in 6 years after each release treatment.

Table 6–*P*-values for treatment sources of variation and orthogonal contrasts by variable and year

Variable and year	Treatment variation	Orthogonal contrasts: None x treatment	Manual x chemical	Glyphosate x fosamine	Manual 1 x manual 2, 3	Manual 2 x manual 3	Manual x comb.
				P-value			
Tree height:							
1979	0.190	0.037	0.253	0.824	0.465	0.111	0.873
1980	.480	.122	.299	.663	.562	.289	.906
1981	.384	.205	.110	.410	.408	.407	.808
1982	.294	.192	.066	.486	.285	.489	.360
1983	.201	.085	.082	.507	.196	.556	.272
1984	.193	.055	.106	.493	.229	.585	.269
1986	.091	.010	.106	.521	.343	.882	.225
Stem caliper at 30 centimeters:							
1980	.107	.036	.049	.519	.445	.227	.832
1983	.009	.002	.011	.314	.155	.580	.222
1984	.015	.002	.029	.348	.328	.736	.164
1986	.028	.002	.098	.385	.341	.836	.253
Diameter breast height:							
1986	.050	.005	.094	.436	.324	.847	.205
Crown width:							
1984	.073	.023	.058	.268	.194	.907	.158
1986	.028	.002	.103	.421	.323	.656	.110
Height to widest crown:							
1984	.111	.556	.358	.188	.013	.239	.932
1986	.596	.894	.369	.964	.182	.203	.533

Table 7—Average initial and attained height, height increment, and percentage gain in 6 years after each release treatment

Release treatment	Trees alive, 1986	Initial height, 1980	Attained height, 1986	Height increment, 1980-86	Gain
	Number	*– – – – – – – – – – – – – Centimeters*	*– – – – – – – – – – – – – – –*		*Percent*
None	189	110.6	462.3	350.9[a]	415
Manual 1	193	135.2	636.2	500.2	468
Manual 2	187	135.7	595.8	459.3	436
Manual 3	196	120.7	587.9	467.6	489
Glyphosate	194	118.0	531.6	412.4	446
Fosamine	196	124.1	566.1	441.8	455
Manual plus fosamine	187	131.9	552.7	419.9	416
All treatments	1342	125.2	561.8	436.0	447

[a] Height increment is based on surviving trees; thus, it differs slightly from a direct subtraction of 1980 average height from 1986 average height.

An orthogonal comparison confirmed that the average height for trees not released was less in 1986 (P = 0.01) than the average for all trees released—462 vs 578 centimeters. Average total height 6 years after manual release exceeded average total height 6 years after herbicide release (P = 0.106)—607 vs 549 centimeters.

Average total height did not differ significantly in other orthogonal comparisons: glyphosate vs fosamine treatment, manual 1 vs manual 2 and 3, manual 2 vs manual 3, or manual vs manual plus fosamine.

In 6 years, gain in height averaged 415 percent for unreleased trees to 489 percent for those manually released three times (table 7). Statistical probability was nearly the same (P = 0.086) for differences among treatment means when comparisons were made with 6-year height increment as the variable instead of total height. Height increment for trees not released averaged 351 centimeters and for those released averaged 450 centimeters (table 7); again, the difference between means was highly significant, P = 0.01. Height increment in manual treatments exceeded height increment in chemical treatments (P = 0.114), 476 vs 427 centimeters, and height increment in manual treatments exceeded height increment in the manual plus fosamine treatment (P = 0.148), 476 vs 420 centimeters. Differences among means in the other three orthogonal contrasts—glyphosate vs fosamine, manual 1 vs manual 2 and 3, and manual 2 vs manual 3—did not differ significantly.

Stem diameter—From 1980 to 1986, average stem diameter at 30 centimeters increased from 15 to 102 millimeters, nearly a sevenfold increase (682 percent). As with height, diameter gain differed greatly by area, with increases of 11.26, 9.73, 5.99, and 4.76 times the 1980 diameter, respectively, at Howell Ridge, Bailey, Farmer Roundtop, and Popo Maple (table 25). The largest numerical increase occurred at Popo Maple, the least at Farmer Roundtop—103 vs 67 millimeters.

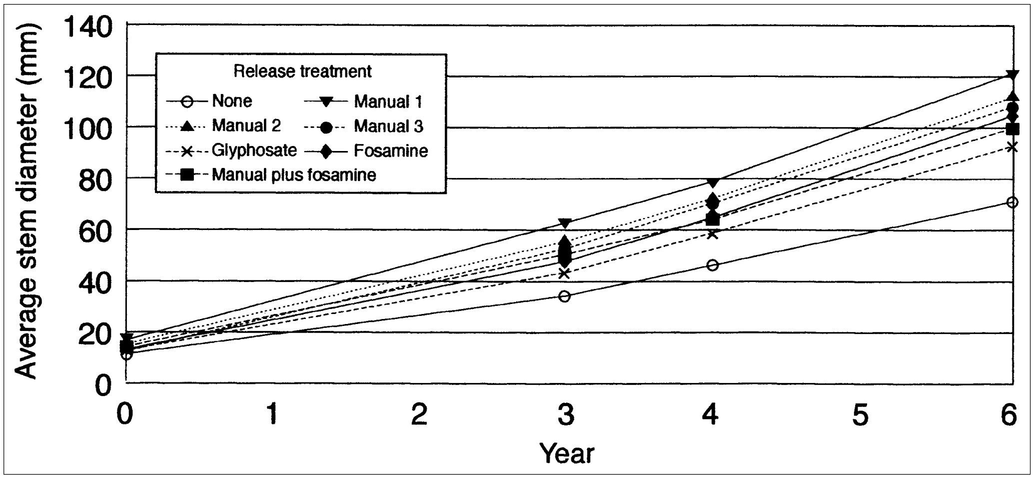

Figure 6—Average stem diameter at 30 centimeters attained by Douglas-firs in 6 years after each release treatment.

Average stem diameter of study trees differed among areas in 1980 and also 6 years later. The largest and oldest trees (Popo Maple) averaged 130 millimeters. The youngest and initially smallest trees (Howell Ridge) were now next smallest, averaging 86 millimeters. Average tree diameter at Bailey also changed upward one rank, averaging 110 millimeters.

As with total height, average stem diameter differed substantially among treatments in 1980 and at every examination afterward (fig. 6, tables 6 and 25). Diameter means among treatments differed in 1980 ($P = 0.107$), and the variation has increased since ($P < 0.028$). Average stem diameter in 1986 ranged from 121 millimeters for the manual 1 treatment to 71 millimeters for unreleased trees (table 8).

An orthogonal comparison confirmed that the average stem diameter for trees not released was significantly less in 1986 ($P = 0.002$) than the average for all trees released—71 vs 107 millimeters (table 8). Average stem diameter 6 years after manual release exceeded average stem diameter 6 years after herbicide release ($P = 0.098$)—114 vs 99 millimeters. Average stem diameter (and d.b.h.) did not differ significantly for the other four orthogonal comparisons (table 6).

The 6-year gain in stem diameter at 30 centimeters averaged 605 percent for unreleased trees to 749 percent for those manually released three times (table 8). Statistical probability was slightly less but still significant ($P = 0.035$) that treatment means differed when comparisons were made with 6-year stem diameter increment as the variable instead of stem diameter. Stem diameter increment for trees not released averaged 59 millimeters, for those released 91 millimeters (table 8); the difference is significant and the probability the same as in the comparison using stem diameter ($P = 0.002$). Diameter increment in manual treatments exceeded diameter increment in herbicide treatments ($P = 0.148$), 97 vs 86 millimeters. Means in the other four orthogonal comparisons did not differ.

Treatment ranking of stem diameters was the same whether based on measurement at 30 centimeters or at breast height, with one manual release first and the control last (fig. 7, tables 8 and 25).

Table 8—Average initial and attained stem diameter at 30 centimeters, diameter increment, and percentage gain in 6 years after each release treatment

Release treatment	Trees with diameter at 30 cm, 1986	Initial stem diameter, 1980	Attained stem diameter, 1986	Stem diameter increment, 1980-86	Gain
	Number	*Millimeters*			*Percent*
None	189	11.6	70.8	59.1[a]	605
Manual 1	193	17.6	120.8	103.1	682
Manual 2	187	17.5	111.3	93.6	629
Manual 3	196	14.7	108.6	94.1	749
Glyphosate	194	12.8	93.5	80.6	725
Fosamine	196	14.2	104.9	90.6	734
Manual plus fosamine	187	16.2	101.3	85.0	621
All treatments	1342	14.9	101.6	86.6	677

[a] Stem diameter increment is based on surviving trees; thus, it differs slightly from a direct subtraction of 1980 average stem diameter from 1986 average stem diameter.

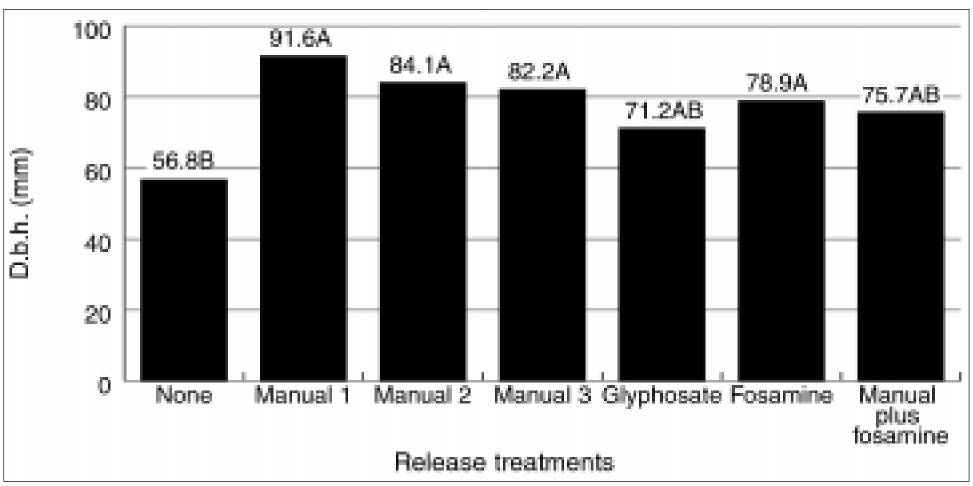

Figure 7—Average stem diameter at breast height attained by Douglas-firs in 6 years after each release treatment. Averages followed by the same letter do not differ significantly by Duncan's (1955) test at the 0.05 probablility level.

Figure 8—Crown width of Douglas-firs and threat of overtopping from hardwoods differed by treatment: fosamine (top left), one manual treatment (top right), and no treatment (lower left) at Bailey, March 1985.

Crown—Average radius of tree crowns also differed by area and treatment. Differences were visibly evident in 1984 (fig. 8); therefore, crown radius was measured then and again in 1986. As might be predicted, crown radius was widest at Popo Maple, where the trees were older, and next widest at Bailey (table 9).

Table 9—Average crown radius and height to widest crown by treatment, unit, and year

	Treatment							
Area	None	Manual 1	Manual 2	Manual 3	Glyphosate	Manual plus fosamine	Fosamine	All
				Centimeters				
				Crown radius 1984				
Farmer Roundtop	164	218	160	203	136	208	172	180
Howell Ridge	165	173	179	196	178	176	96	166
Bailey	158	255	208	213	187	200	247	209
Popo Maple	202	332	325	270	246	263	290	275
Average	172	245	218	220	187	212	201	208
				Crown radius 1986				
Farmer Roundtop	224	280	239	286	186	265	231	244
Howell Ridge	225	275	255	292	267	273	158	249
Bailey	168	360	326	321	309	311	358	308
Popo Maple	289	417	391	362	340	343	371	359
Average	227	333	303	315	276	298	280	290
				Height to widest crown 1984				
Farmer Roundtop	123	112	107	114	109	125	108	114
Howell Ridge	111	101	97	96	99	111	98	102
Bailey	111	146	112	78	118	109	104	111
Popo Maple	131	146	135	124	128	151	145	137
Average	119	126	113	103	113	124	113	116
				Height to widest crown 1986				
Farmer Roundtop	170	171	150	158	156	172	166	163
Howell Ridge	149	150	158	164	153	159	136	153
Bailey	167	165	168	147	161	145	153	158
Popo Maple	186	220	211	172	189	181	205	195
Average	168	176	172	160	165	164	165	167

Six years after treatment, the limb span averaged significantly less (P = 0.002) on trees not released than on those that had been released (tables 6 and 9). The limb span averaged 227 centimeters for unreleased trees and 301 centimeters for released trees. Manually released trees had a greater crown radius than those chemically released (317 vs 287 centimeters, P = 0.103), and crowns of manually released trees also were wider than crowns of trees manually released and later sprayed with fosamine (317 vs 280 centimeters, P = 0.110). Means for the other three orthogonal contrasts did not differ.

In 1986, the height aboveground to the longest branches did not differ significantly among treatments, ranging from 160 centimeters for the manual 3 treatment to 176 for the manual 1 treatment. Two years previously, the averages for the same two treatments were 103 and 126 centimeters and differed significantly (P = 0.013).

Volume growth and relative costs—Six years after release, the planted Douglas-firs differed slightly in survival and substantially in growth among treatments. There also were large differences in the cost of treatment. To compare results in useful, integrated terms, survival and growth data were used to calculate cubic volumes produced per acre; both volumes and costs were expressed as ratios relative to no release.

The comparisons were made by using averages developed from cost information collected at the Forest and District level for treatments applied on the study areas. Costs per acre for chemicals and their application were the same for all four areas because spray treatments were covered by Forest-wide contracts. Costs of mechanical release and administration differed substantially by District, year, and whether it was a separate task or part of an effort extending beyond study area boundaries. Costs and returns were compared directly without figuring in the carrying costs for each treatment. The estimated volumes, the relative costs, and the relative gains for each release method were calculated as if 400 trees per acre of this size and age comprised full stocking.

The volume of stemwood present 6 years after release differed substantially among treatments (fig.1, table 10). Relative to no release, one manual release treatment produced four times as much volume and the other two manual release treatments three times as much volume. Spraying with glyphosate produced the least treatment effect, about two times as much volume as no release.

One manual release yielded the highest return for the money expended relative to the value produced without release (tables 11 and 26). The estimated economic gain was 3.5 times as much. Spraying fosamine produced the next highest return, 2.2 times as much, and using manual release followed by fosamine spraying a year later produced the least return for release, 1.32 times as much as no release.

Changes in Shrub Competition

Shrub competition was measured on square 0.09-meter plots (1 ft^2) in 1980 to 1983, positioned 0.6 and 1.8 meters (2 and 6 ft) away from the trees monitored for growth. In 1984 and 1986, shrub cover was estimated on 16.2-square-meter (4-milacre) circular plots with the sample trees used as plot centerpoints. The information produced by these two measurement methods differs, but each method provided insight on the effect of treatment on competition.

Table 10—Stem volume per acre 6 years after each release treatment

Release treatment	Stand characteristic						
	Average height	Average stem caliper	Average volume per tree	Survival	Trees per acre	Volume per acre	Relative volume[a]
	Centimeters	*Millimeters*	*Cubic centimeters*	*Percent*	*Number*	*Cubic meters*	
None	462.3	70.8	6066.8	94.5	378	2.293	1.00
Manual 1	636.2	120.8	24305.0	96.5	386	9.382	4.09
Manual 2	595.8	111.3	19322.3	93.5	374	7.227	3.15
Manual 3	587.9	108.6	18152.3	98.0	392	7.116	3.10
Glyphosate	531.6	93.5	12166.8	97.0	388	4.721	2.06
Fosamine	566.1	104.9	16308.4	98.0	392	6.393	2.79
Manual plus fosamine	552.7	101.3	14848.3	93.5	374	5.553	2.42
Average	561.8	101.6	15182.3	95.9	383	5.815	

[a] Volume relative to volume for trees not released.

Table 11—Comparative volume and value produced by each release treatment

Release treatment	Volume per acre	Value/acre at $100/cubic meter	Release cost per acre	Net value	Relative gain[a]
	Cubic meters	– – – – – – – – – – *Dollars*	– – – – – – – – – –		
None	2.293	229	0	229	1.00
Manual 1	9.382	938	128	810	3.54
Manual 2	7.227	723	231	492	2.15
Manual 3	7.116	712	312	400	1.75
Glyphosate	4.721	472	130	342	1.49
Fosamine	6.393	639	125	514	2.24
Manual plus fosamine	5.553	555	253	302	1.32

[a] Value gained relative to value for trees not released.

Table 12—Shrub cover at 0.6 and 1.8 meters from Douglas-fir trees; averages for number of stems, diameters, and heights, 1980-83

Distance and year	Stems per square meter	Stem diameter Total sample	Stem diameter Average	Shrub height Total sample	Shrub height Average
	- - - *Number* - - -		*Centimeters*	*Number*	*Centimeters*
At 0.6 meter:					
1980	19.9 A[a]	682	1.12A	682	69.4A
1981				715	54.9B
1982				722	60.4B
1983	26.6 A	647	1.13A	648	62.2A
At 1.8 meters:					
1980	19.3A	717	1.13A	717	72.4A
1981				745	66.1A
1982				772	68.2A
1983	27.7A	702	1.16A	702	71.2A

[a] Means for the same attribute and year followed by the same letter do not differ significantly for 0.6 and 1.8 meters by Duncan's (1955) test at the 0.05 probability level.

Shrub size—The number of shrub stems, their diameters, and their heights averaged nearly the same at 0.6 and 1.8 meters away from marked trees at the start of the study (table 12). By 1983, the average number of stems per square meter had increased by at least one-third (19.9 to 26.6, 19.3 to 27.7) at both distances, but average stem diameters hardly changed. On plots 0.6 meter from the trees, average shrub height was reduced 14.5 centimeters by 1981; half of that loss was regained by 1983. On plots 1.8 meters from the trees, the height reduction averaged only 6.3 centimeters and was essentially regained by 1983. The significant differences in average shrub height at 0.6 and 1.8 meters in 1981 and 1982 are attributable to the greater height reductions caused at 0.6 meter by the manual release treatments.

Area means differed initially for samples from both 0.6 and 1.8 meters in number of stems, stem diameters, and total heights (tables 13, 27, and 28). The initial number of stems per square meter was highest at Farmer Roundtop and lowest at Popo Maple for both 0.6-meter (range 23.9 to 15.0) and 1.8-meter (range 25.8 to 16.2) samples. There still were differences at 1.8 meters by 1983, but the order had changed with the number of stems then greatest at Popo Maple. Stem diameters were larger initially at Farmer Roundtop and Popo Maple than at Howell Ridge and Bailey, but by 1983 differences at either 0.6 or 1.8 meters had diminished.

At the start of the study, shrubs were twice as tall (average, nearly 1 meter) at Farmer Roundtop and Popo Maple as at Howell Ridge and Bailey. Treatments reduced the average shrub height at three areas but not at Bailey, where averages showed an increase each year. At two areas, shrubs did not regain their initial average height by 1983 on either 0.6- or 1.8-meter plots.

Table 13—*P*-values for area and treatment sources of variation in cover attributes for both kinds of vegetation plots

	Sources of variation			
	Area[a] (df=3)		Treatment (df=6)	
Attribute and year	At 0.6 meter	At 1.8 meters	At 0.6 meter	At 1.8 meters
	P-values for square 0.09-meter plots			
Number of stems:				
1980	0.009	0.032	0.169	0.717
1983	.346	.145	.237	.193
Stem diameter:				
1980	.000	.000	.316	.311
1983	.588	.427	.557	.707
Stem height:				
1980	.000	.000	.161	.461
1981	.004	.001	.000	.012
1982	.002	.001	.000	.002
1983	.001	.009	.007	.201
	P-values for circular 16.2-square-meter plots			
Total cover:				
1984	.000		0.011	
1986	.000		.071	
Adjacent cover:				
1984	.001		.058	
1986	.366		.297	
Height of dominant species:				
1984	.111		.182	
1986	.138		.479	
Height of secondary species:				
1984	.001		.010	
1986	.003		.114	

[a] Tests of significance among areas are approximate and provide supporting evidence for blocking.

Before treatment, averages for number of stems and stem diameter did not differ significantly among treatment plots at either the 0.6- or 1.8-meter distances (tables 13 to 15). Height averages did not differ significantly at the 1.8-meter distance, but there were significant differences at the 0.6-meter distance. Heights in the glyphosate plots were taller, and in the manual 2 and 3 plots were shorter, than the rest.

Release treatments had no significant effect on shrub stem diameters, caused some differences in average number of stems, and caused large differences in average shrub height (tables 13 to 15). The number of stems per square meter increased in all treatments except for glyphosate at 0.6 meter, and the rankings changed. The average increase in stem numbers ranged between 1.8 and 7.3 per square meter for all treatments except for the two and three manual releases, where the increases ranged from 14.3 to 17.6. Repeated cutting is the likely cause for increasing these stem numbers per square meter by about 80 percent.

Shrubs in all treatments but one averaged less than 1 meter in height in the 1980 to 1983 period (tables 13 to 15). Though initially similar in height, untreated shrubs became significantly taller by 1983 than those subjected to release treatments. Without treatment, the increase in shrub height averaged 19 centimeters from 1980 to 1983, but average height in 1983 was 5 centimeters less than it was in 1982.

All release treatments except fosamine reduced average shrub height at both 0.6- and 1.8-meter distances from the trees. Average heights for shrubs treated only with fosamine remained in a steady state, neither losing nor gaining appreciable amounts. Shrub recovery in most of the other treatments was not sufficient to return height averages to pretreatment levels by 1983. The one manual release treatment was an exception; although average height was reduced substantially by the treatment, recovery by 1983 was rapid enough so that heights averaged 5.9 and 9.6 centimeters greater at 0.6 and 1.8 meters, respectively, than initial heights. Initial shrub height was reduced at 1.8 meters from released trees in all three manual release treatments—an unexpected effect outside of the radius specified for manual release.

Shrub cover—In late 1984, four growing seasons after initial treatment, total cover on study areas averaged 60 percent, as determined by ocular estimates on 4-milacre plots (table 29). Total cover increased to 71 percent in the next two seasons, but the amount judged to be directly impinging on tree growth decreased from 33 to 19 percent. Average height of the dominant competitor near sample trees was 178 centimeters in late 1984 and 204 centimeters 2 years later.

Total cover was less at Howell Ridge than at the other three locations in both 1984 and 1986 (tables 13 and 29). Amount of closely adjacent cover also was less at Howell Ridge in 1984, but the differences narrowed by 1986. The dominant and secondary shrubs also were shorter at Howell Ridge than elsewhere.

Total cover was significantly greater (P = 0.011, 0.071) in untreated areas than treated areas—78 vs 57 percent in 1984, and 85 vs 69 percent in 1986 (tables 13 and 16). Among release treatments, differences in total cover did not differ significantly in either 1984 or 1986.

Table 14—Shrub cover at 0.6 meter from Douglas-fir trees; averages for number of stems, diameters, heights, and treatments, 1980-83

Release treatment and year	Stems per square meter	Stem diameter		Shrub height	
		Total sample	Average	Total sample	Average
	– – – – – *Number*	– – – – –	*Centimeters*	*Number*	*Centimeters*
None:					
1980	18.0A[a]	104	1.13A	104	71.3AB
1981				116	83.3A
1982				121	95.9A
1983	23.7AB	102	1.20A	102	91.0A
Manual 1:					
1980	16.6A	77	1.10A	77	64.8AB
1981				85	39.8B
1982				82	60.8B
1983	18.4B	71	1.10A	71	70.7AB
Manual 2:					
1980	17.1A	76	1.08A	76	61.6B
1981				93	38.9B
1982				97	40.4CD
1983	31.4AB	106	1.11A	106	49.6BC
Manual 3:					
1980	20.0A	94	1.10A	94	60.7B
1981				114	40.2B
1982				118	35.7D
1983	36.7A	100	1.06A	100	33.8C
Glyphosate:					
1980	19.9A	108	1.22A	108	88.6A
1981				91	72.0A
1982				87	66.1B
1983	19.9AB	77	1.12A	78	66.1AB
Fosamine:					
1980	24.4A	109	1.08A	109	65.1AB
1981				97	65.6A
1982				103	68.0B
1983	27.2AB	92	1.18A	92	62.6B
Manual plus fosamine:					
1980	23.7A	114	1.11A	114	73.6AB
1981				119	44.5B
1982				114	56.0CB
1983	29.1AB	99	1.13A	99	61.6B

[a] Means for the same attribute and year followed by the same letter do not differ significantly by Duncan's (1955) test at the 0.05 probability level.

Table 15—Shrub cover at 1.8 meters from Douglas-fir trees; averages for number of stems, diameters, heights, and treatments, 1980-83

Release treatment and year	Stems per square meter	Stem diameter		Shrub height	
		Total sample	Average	Total sample	Average
	– – – – – – *Number*	*– – – – –*	*Centimeters*	*Number*	*Centimeters*
None:					
1980	20.1A[a]	106	1.19A	106	78.0A
1981				120	90.3A
1982				127	101.4A
1983	27.4AB	120	1.22A	120	96.1A
Manual 1:					
1980	18.0A	107	1.16A	107	69.4A
1981				104	59.8BC
1982				105	78.9AB
1983	21.0AB	94	1.22A	94	79.0AB
Manual 2:					
1980	23.5A	103	1.08A	103	69.1A
1981				110	57.8BC
1982				122	52.3C
1983	41.1A	115	1.12A	115	68.3AB
Manual 3:					
1980	18.7A	89	1.08A	89	62.1A
1981				113	50.4C
1982				119	47.3C
1983	35.1AB	108	1.09A	108	43.2B
Glyphosate:					
1980	16.0A	103	1.17A	103	84.0A
1981				89	72.9AB
1982				89	63.5BC
1983	19.2B	77	1.15A	77	71.4AB
Fosamine:					
1980	20.4A	107	1.12A	107	70.2A
1981				94	69.6ABC
1982				99	72.0BC
1983	26.2AB	91	1.16A	91	69.9AB
Manual plus fosamine:					
1980	18.1A	102	1.11A	102	73.7A
1981				115	61.5BC
1982				111	62.1BC
1983	23.8AB	97	1.15A	97	70.3AB

[a] Means for the same attribute and year followed by the same letter do not differ significantly by Duncan's (1955) test at the 0.05 probability level.

Table 16–Average vegetation cover around trees in 1984 and 1986, by treatment and attribute

Treatment	Total cover	Adjacent cover	Height of cover: Dominant species	Height of cover: Secondary species
	Percent	*Percent*	*Centimeters*	*Centimeters*
None:				
1984	77.7A[a]	44.0A	280A	168A
1986	84.9A	38.3A	273A	177A
Manual 1:				
1984	61.4B	41.6AB	197AB	147AB
1986	70.9B	18.9AB	241A	159AB
Manual 2:				
1984	56.4B	27.0BC	146B	101C
1986	66.8B	17.5AB	193A	127B
Manual 3 :				
1984	56.3B	25.5BC	135B	98C
1986	71.6B	16.4AB	207A	133B
Glyphosate:				
1984	50.2B	23.6C	160AB	121BC
1986	66.3B	13.7AB	174A	131B
Fosamine:				
1984	57.4B	36.2ABC	171AB	132ABC
1986	66.3B	12.7B	160A	138AB
Manual plus fosamine:				
1984	60.9B	30.9ABC	156AB	148AB
1986	69.7B	17.2AB	178A	130B
All:				
1984	60.0	32.7	178	131
1986	70.9	19.3	204	142

[a] Attribute means for 1984 or 1986 followed by the same letter do not differ significantly by Duncan's (1955) test at the 0.05 probability level.

Cover judged to be crowding the trees differed significantly among treatments in both 1984 and 1986 (tables 13 and 16). In 1984, the untreated control and manual 1 treatments had very similar amounts of impinging cover and the glyphosate treatment had the least: range among treatments, 44 to 24 percent. In 1986, the difference between the average for untreated areas (38 percent) and those treated with fosamine (13 percent) was significant.

At 280 centimeters, the average height of dominant competitors around nonreleased trees was 83 centimeters more in 1984 than the average for one manual release, the highest average among release treatments. In 1986, the average height of the dominant competitors where no release had been applied was 7 centimeters less than in 1984. The average heights of dominant competitors in 1986 were less in release treatments than without release, but the differences were not significant.

Relative Height of Trees and Shrubs

When the study began, shrub canopy 0.6 meter from sample trees averaged more than half as tall as the trees: range, 45 to 75 percent (tables 17 and 30). Shrub canopy in the untreated and the glyphosate plots averaged markedly closer to tree height than in other treatments. In 1983, after all treatments had been applied and trees had 3 more years of growth, shrub canopy in the untreated plots averaged one-third of tree height but only 11 percent of tree height where three manual treatments had been applied. By 1986, dominant competitors averaged 59 percent of tree height in untreated areas, only one-third of tree height in treated areas. Relative to Douglas-fir, height of salmonberry decreased in all treatments from 1984 to 1986, but relative heights of red alder, red elder, and vine maple increased in some treatments and decreased in others.

Species diversity was not reduced by any of the release treatments. In fact, in both 1984 and 1986, as many or more species were dominant competitors around Douglas-fir crop trees in all release treatments than around crop trees in the control (tables 18 and 30). Only 10 to 15 species were dominant competitors in the various treatments, but on many plots, these same species and others were present as subdominants.

Based on frequency of occurrence, just five species comprised the dominant competing vegetation near crop trees 80 percent or more of the time: salmonberry, thimbleberry, sword-fern, red alder, and salal (table 18). Salmonberry was the most frequent competing dominant in every treatment, with the lowest occurrence (27.6 percent) in the manual 3 treatment and equally high levels (48.7 percent) in the manual 1 and manual plus fosamine treatments. Thimbleberry was the next most common dominant, occurring at a frequency of 12 percent or more in every treatment. Frequency of dominant competition by sword-fern, red alder, and salal differed substantially among treatments with only red alder frequency apparently related to the kind of treatment; in 1986, its dominance as a competing species was much less in treatments involving herbicides than in manual treatments or the control.

Discussion and Conclusions

Release Effects

Every release treatment tested in this study improved the growth and development of the planted Douglas-firs. Even the least effective treatment, glyphosate, produced an 18-percent average gain in height, a 36-percent gain in stem diameter, and twice as much stem volume as for unreleased trees (table 19). Manually cutting woody species once in a 1.2-meter radius around the tree improved growth the most, four times as much volume 6 years after release as for unreleased trees.

Single release treatments produced better results than multiple treatments and, of course, were more cost effective (table 11). Though tree height and stem diameter for trees released manually two or three times averaged only slightly smaller than for those released once, one-fourth less volume was produced on the former. Similarly, a fosamine spraying subsequent to manual release resulted in less growth than for either the single manual release or fosamine treatment alone. Under the conditions tested, the initial treatment proved of overriding importance in providing release.

Table 17—Relative height of competing vegetation to Douglas-fir, by treatment and year

Category and year	Release treatment						
	None	Manual 1	Manual 2	Manual 3	Glyphosate	Fosamine	Manual plus fosamine
	Percent						
Shrub average at 0.6 meter:							
1980	64	48	45	50	75	52	56
1981	53	21	21	24	46	38	25
1982	47	23	16	16	32	31	25
1983	34	20	15	11	24	21	21
Dominant competitors:							
1984	86	45	36	35	46	45	42
1986	59	38	32	35	33	28	32
Red alder:							
1984	172	96	77	62	82	85	78
1986	142	95	105	92	87	69	60
Vine maple:							
1984	74	—	15	55	67	45	43
1986	62	—	—	44	47	51	33
Red elder:							
1984	71	34	21	31	46	47	37
1986	63	—	45	43	51	48	47
Salmonberry:							
1984	55	37	35	33	42	46	44
1986	42	29	29	28	30	29	34

Table 18–Competitive species dominant adjacent to Douglas-fir trees in 1986, by treatment

Species	Treatment						
	None	Manual 1	Manual 2	Manual 3	Glyphosate	Fosamine	Manual plus fosamine
	Frequency of occurrence (percent)						
Acer circinatum	4.2			0.5	2.6	0.5	1.1
Acer macrophyllum		0.5					
Alnus rubra	18.0	11.9	9.1	16.3	4.1	1.0	1.6
Baccharis pilularis	1.6	0.5			1.0		1.1
Berberis spp.			2.1				
Corylus cornuta var. *californica*	0.5						
Gaultheria shallon	4.2	0.5	7.5	18.4	2.1	15.8	7.5
Holodiscus discolor					1.0	0.5	
Menziesia ferruginea		2.6					0.5
Picea sitchensis					0.5		
Polystichum munitum	12.2	8.8	18.7	16.8	21.1	15.8	8.0
Pseudotsuga menziesii	0.5	3.1	1.1	3.1	2.6	4.6	1.1
Pteridium aquilinum		6.7	4.3	1.0	5.2	1.0	4.3
Ribes sanguineum			0.5				
Rubus parvifolius	21.7	13.5	11.8	14.8	18.0	15.3	23.5
Rubus procera		0.5					
Rubus spectabilis	34.4	48.7	41.7	27.6	34.5	36.7	48.7
Rubus ursinus						0.5	
Salix spp.		0.5			2.1	3.1	

Table 18–Competitive species dominant adjacent to Douglas-fir trees in 1986, by treatment (continued)

	Treatment						
Species	None	Manual 1	Manual 2	Manual 3	Glyphosate	Fosamine	Manual plus fosamine
	Frequency of occurrence (percent)						
Sambucus callicarpa	1.1		1.1	0.5	0.5	3.1	0.5
Tsuga heterophylla		0.5		0.5			
Vaccinium ovatum		0.5	1.1		3.1	1.5	1.1
Vaccinium parvifolium	1.6	1.0	1.1	0.5	1.5	0.5	1.1
Observations (number of plots)	189	193	187	196	194	196	187
Species (number), 1984	10	13	13	10	15	11	12
Species (number), 1986	11	15	12	11	15	14	13

Table 19—Gain in Douglas-fir height, stem diameter, and volume after release treatment compared to trees not released

	Attribute		
Treatment	Height	Stem diameter	Volume
	Percent		
None	100	100	100
Manual 1	143	174	409
Manual 2	131	158	315
Manual 3	133	159	310
Glyphosate	118	136	206
Fosamine	126	153	279
Manual plus fosamine	120	144	242

One might logically expect more tree growth after multiple release treatments than after a single treatment. There is no obvious explanation for the same or even less growth response after multiple treatments. Tree heights in the single and double manual release treatments averaged slightly but not significantly taller than in other treatments at the start of the study (tables 6 and 7) and the trees also were somewhat larger in stem diameter (table 8). Trees in the single manual release treatment retained their starting rank; in the double manual release treatment they did not. Similarly, trees in the manual plus fosamine treatment were initially in third position but dropped to fifth by 1986. Tree mortality was higher in the double manual release and the manual plus fosamine treatments than in the single and triple manual release treatments. Slightly less growth in height and diameter on a few less stems resulted in a sizable difference in volume.

Trees grew somewhat better in height ($P = 0.11$) and diameter ($P = 0.10$) after manual release than after release with herbicide. Again, there is some basis for expecting the opposite result. Manual release removed vegetation immediately around the trees, whereas herbicide release reduced competing vegetation across the entire plot. Area-wide reduction of vegetation might curtail moisture depletion better than spot release around the trees. On the other hand, prompt removal of vegetation might better conserve moisture and increase light near the released trees than is accomplished by the slower vegetation attrition following release with herbicide. A possible adverse herbicide effect on tree growth also should be considered. Visible damage to terminal and side shoots was observed on some trees in the first and second seasons after spraying with either glyphosate or fosamine. Such an apparent minor setback might be sufficient to prevent herbicide-treated trees from keeping pace with those released manually.

Release treatments temporarily reduced but by no means eliminated shrub and hardwood competition. Six years after release, total cover around trees not released averaged 85 percent; around released trees, it averaged 69 percent. Height of the dominant competitors averaged nearly two-thirds of tree height in untreated areas and one-third of tree height in treated areas. Manual release drastically lowered the average height of cover within 1.2 meters of the individual tree, but cover farther away developed relatively unimpeded; in contrast, herbicide release affected the entire plot area and all species present. Manual release also reduced height of all woody plants equally, whereas the herbicides affected species unequally. The most visible herbicide effects were observed on salmonberry, the chief competitor, and on red alder, thimbleberry, and vine maple.

Study Topics

Better growth as well as the cost-effectiveness of manual release are more clearly demonstrated by results of this study than in the few other comparisons involving Douglas-fir released manually or with herbicide (Harrington and others 1995, McDonald and Fiddler 1986, Schneider and Knowe 1993). In this study, differences in average stem diameter of released and unreleased trees were statistically significant ($P < 0.05$) in the third year after treatment. Height differences also approached significance in the third year. Manual release produced the most volume in the first 6 years; whether this trend continues may depend on the greater number of alder trees present to compete with Douglas-fir in areas of manual release than in those with herbicide release (table 18). The longer term benefits of the release treatments should and could readily be determined by remeasurement of the study plots.

A new and closer look is needed at the level of damage caused by glyphosate, fosamine, and other herbicides used to release Douglas-fir from competing vegetation. Damage has been observed and reported among results of other studies (Cole and others 1989, Harrington and others 1995, King and Radosevich 1985), but trees released by herbicides can outgrow unreleased trees despite the initial damage they sustain. How much potential growth is lost from such initial damage? Does manual release realize more of the full growth potential of Douglas-fir than herbicide release? Fine-tuning is needed to identify the best herbicide, dosage, and timing required in different vegetation complexes to maximize results when Douglas-firs are released with herbicides.

Better guidelines need to be developed for judging on a timely basis where release from competing vegetation is critical for development of the desired conifer stand, where release will materially accelerate growth, and where it is not really needed. In both the CRAFTS study (Harrington and others 1995) and this study, sites were selected based on an impending vegetation management problem. In neither study did the apparent problem prove critical for adequate conifer development. In the untreated areas, conifer survival was high and heights and diameters increased nicely but not as much as in treated areas. In this study, overtopping became critical in only one of the four untreated areas: at Bailey, two-thirds of the unreleased trees are now overtopped by faster growing red alders. Harrington and others (1995) suggest a threshold for release is reached when 15 to 25 percent of desired trees are overtopped.

Crown width and height aboveground of the longest limb were measured to characterize visibly evident differences among treatments in tree crown size and vigor. The data confirmed that crown radius differed by treatment and averages ranked in nearly the same order as for stem diameter. Trees thriving under competition have long limbs and a dense compliment of needles. Trees under shade or with heavy side competition have shorter, smaller diameter limbs and a substantially thinner complement of needles. Where competing vegetation is not overly dense, long Douglas-fir limbs can be found growing within the shrub canopy. It seems possible to develop and use crown width and vigor as a diagnostic tool for identifying which Douglas-fir stands or individual trees could benefit most from release.

Applications

Results of this study confirm once again that early reduction of competition aids the growth of young Douglas-fir trees. This commonly accepted principle (Walstad and Kuch 1987) has been demonstrated specifically for Douglas-fir in the Coast Ranges in a variety of studies; i.e., Brand (1986), Chan and Walstad (1987), Cole and Newton (1987), Gourley and others (1990), Howard and Newton (1984), Jaramillo (1988), Miller and Obermeyer (1996), Newton and Preest (1988), O’Dea and others (1994), Schneider and Knowe (1993), Stein (1995), Tung and others (1986), and Walstad and others (1986). But studies directly comparing manual and herbicide release methods side by side on a practical scale are sparse. As shown by this study, manual release can be as good and as cost-effective as the herbicides tested.

The study results also demonstrate that the land manager has a range of options when young coastal Douglas-fir plantations are under heavy competition from associated vegetation. The options range from doing nothing to applying one of several release treatments and perhaps some later followup. Choice of options depends on the land manager’s objective for the site, ranging from letting nature take its course to lightly or strongly nudging the ecosystem in the desired direction.

Figure 9—After 6 years, overtopping red alders dominated the untreated area (lower left) but were sparse in the glyphosate (left, center), fosamine, and manual plus fosamine treatments (right) at Bailey.

Even without release, most planted Douglas-firs outgrew their competitors under the vegetation conditions prevailing in this study. Growth of unreleased trees was substantially slower than for released trees, however, and the certainty of success was less until years passed and trees proved they could emerge from among competitors. Site preparation and use of large stock helped position the Douglas-firs to develop without benefit of release. Sites were prepared by broadcast burning at all locations except Farmer Roundtop and planted with either 2-0 or 2-1 stock (table 3). Lack of site preparation might explain why the planted Douglas-firs at Farmer Roundtop averaged next to largest in 1980 but were smallest in 1986. This shift also could be due to differences in intrinsic site quality, however.

Clearly, Douglas-fir benefited from all release treatments. The release treatments represent a second cultural step taken to foster growth of the planted trees. A release effort also is precautionary—a step taken to prevent loss of a plantation when competing vegetation appears to threaten its existence. Far better to increase tree growth through timely release than chance losing the plantation and having to start over.

Species diversity was temporarily improved by several of the release treatments. *Temporary* must be emphasized, for treatments that led to greater variety among dominant associated species also produced faster growth of Douglas-fir. Thus, tree crowns will close sooner, thereby leading to crowding out of some associated species, the reduction of dominance and cover of others, and an increase in shade-tolerant understory.

By 1986, shrub species such as salmonberry, thimbleberry, and salal were generally overtopped by and no longer a critical threat to the Douglas-firs. The rapid development of red alder, however, threatens to overtop many Douglas-firs and partly negate gains from the release treatments tested (figs. 8 and 9). Developing stands must be tended to ensure that early gains in growth of crop trees are not lost because of later overtopping by fast-developing hardwoods.

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Units of Measure

Most data were collected, summarized, and reported in metric units. For reader convenience, English equivalents are given in parentheses up to the “Results” and “Discussion” sections, where this practice seemed too repetitive and distractive. Also, certain tabular and text numbers are clearer for the primary audience if given in English units, and this has been done. Equivalents for the units of measure used are as follows:

1 millimeter = 0.0394 inch
1 centimeter = 0.3937 inch
1 meter = 3.28 feet
1 kilometer = 0.62 mile
1 hectare = 2.471 acres
1 cubic meter = 1.308 cubic yards

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Appendix

Table 20—Damage to associated species at each area after treatment with glyphosate

Area and species	Examination, number of observations, and damage rating							
	– First spring –		– First summer –		–Second spring –		– Second summer –	
	Number	*Index*[a]	*Number*	*Index*	*Number*	*Index*	*Number*	*Index*
Farmer Roundtop:								
Salmonberry	20	5.20	20	5.15	20	5.05	20	5.45
Red alder	5	5.40	5	6.00	5	6.20	5	6.20
Red elder	20	4.55	20	4.05	20	3.45	20	3.05
Sword-fern	20	5.00	20	5.40	20	3.25	20	3.75
Red huckleberry	15	1.67	10	1.80	15	1.73	15	1.67
Salal	*		?	0	*		*	
Bracken	20	6.65	20	1.00	20	1.00	20	1.00
Average		4.75		3.34		3.44		2.11
Howell Ridge:								
Salmonberry	3	3.67	8	3.75	5	0	*	
Vine maple	3	1.00	3	1.00	*		*	
Red elder	20	3.25	20	4.05	20	3.40	20	3.45
Sword-fern	20	.55	20	1.45	20	.25	20	.35
Average		2.12		2.56		1.22		1.90
Bailey:								
Salmonberry	20	5.10	20	5.20	20	5.70	20	5.00
Thimbleberry	20	5.35	20	5.95	20	5.25	20	4.90
Red alder	15	6.53	15	6.53	15	6.07	15	6.07
Red elder	10	2.50	2	5.00	10	4.20	10	4.20
Sword-fern	20	1.70	20	2.75	20	1.65	20	1.35
Salal	*		?	0	?	0	?	0
Average		4.24		4.24		3.81		3.59
Popo Maple:								
Salmonberry	20	4.10	20	4.45	20	4.85	20	5.25
Thimbleberry	20	2.90	20	3.05	20	2.30	20	2.20
Vine maple	20	.95	20	1.05	20	.90	20	.60
Red alder	5	1.20	5	.20	5	0	5	0
Red elder	20	3.55	20	2.80	19	2.53	20	2.25
Sword-fern	20	.05	20	0	20	0	20	0
Red huckleberry	5	.40	5	0	5	.40	5	.20
Salal	*		*		?	0	?	0
Ocean-spray	10	1.60	5	1.60	9	.44	10	.30
Evergreen huckleberry	?	0	?	0	?	0	?	0
Chaparral-broom	*		*		?	0	?	0
Average		1.64		1.46		1.04		.98

Table 20—Damage to associated species at each area after treatment with glyphosate (continued)

Area and species	Examination, number of observations, and damage rating							
	– First spring –		–First summer –		– Second spring –		– Second summer –	
	Number	*Index*[a]	*Number*	*Index*	*Number*	*Index*	*Number*	*Index*
All:								
Salmonberry	63	4.52	68	4.64	65	3.90	60	5.23
Thimbleberry	40	4.13	40	4.50	40	3.78	40	3.55
Vine maple	23	.98	23	.53	20	.90	20	.60
Red alder	25	4.38	25	4.24	25	4.09	25	4.09
Red elder	70	3.46	62	3.98	69	3.40	70	3.24
Sword-fern	80	1.83	80	2.40	80	1.29	80	1.36
Red huckleberry	20	1.04	15	.90	20	1.07	20	.94
Salal	*		?	0	?	0	?	0
Bracken	20	6.65	20	1.00	20	1.00	20	1.00
Ocean-spray	10	1.60	5	1.60	9	.44	10	.30
Evergreen huckleberry	?	0	?	0	?	0	?	0
Chaparral-broom	*		*		?	0	?	0
Average		2.86		2.16		1.66		1.69

* = no observation; ?= damage effect observed on unrecorded number of samples.
[a] Average values based on an index from 0 for no effect to 7 for complete kill observed on designated sample shrubs.

Table 21—Damage to associated species at each area after treatment with fosamine

Area and species	Examination, number of observations, and damage rating							
	– First spring –		– First summer –		– Second spring –		– Second summer –	
	Number	*Index*[a]	*Number*	*Index*	*Number*	*Index*	*Number*	*Index*
Farmer Roundtop:								
Salmonberry	20	4.40	20	4.60	20	4.15	20	4.50
Thimbleberry	5	1.40	5	2.20	10	.50	10	.50
Vine maple	10	4.00	10	5.00	10	3.30	10	2.90
Red alder	5	5.00	5	5.60	5	4.80	5	4.80
Red elder	20	1.55	20	2.25	20	.90	22	1.36
Sword-fern	20	0	20	2.70	20	.10	20	0
Red huckleberry	15	1.20	10	1.80	15	.33	15	.33
Average		2.51		3.45		2.01		2.06
Howell Ridge:								
Salmonberry	5	3.20	5	1.40	5	.20	6	.33
Vine maple	3	1.33	*		*		*	
Red elder	20	1.60	20	3.60	20	1.90	20	2.85
Sword-fern	20	.30	20	.80	20	0	20	.35
Average		1.61		1.93		.70		1.18
Bailey:								
Salmonberry	20	4.20	20	4.10	20	3.05	20	2.60
Thimbleberry	15	1.67	10	1.90	15	1.13	15	1.07
Red alder	20	4.70	20	5.05	20	5.95	20	5.65
Red elder	20	1.70	10	2.00	20	1.80	20	1.95
Sword-fern	20	.75	20	2.00	20	0	20	0
Salal	?	0	*		?	0	?	0
Bracken	?	1.00	*		*		*	
Average		2.00		3.01		1.99		1.88
Popo Maple:								
Salmonberry	20	3.25	20	2.70	20	2.50	20	2.60
Thimbleberry	20	.40	20	.80	20	.60	20	.80
Red alder	10	2.10	10	2.20	10	1.50	10	1.40
Red elder	10	2.40	10	2.60	10	2.60	10	3.50
Sword-fern	20	0	20	0	20	0	20	0
Red huckleberry	10	.60	10	.50	10	.30	10	.40
Salal	*		?	0	?	0	*	
Bracken	*		20	.50	*		*	
Ocean-spray	6	1.83	6	1.83	6	.67	6	.67
Willow spp.	7	0	5	0	7	0	*	
Evergreen huckleberry	*		*		?	0	*	
Chaparral-broom	*		*		?	0	*	
Average		1.32		1.11		.94		1.34

Table 21—Damage to associated species at each area after treatment with fosamine (continued)

Area and species	Examination, number of observations, and damage rating							
	– First spring –		– First summer –		– Second spring –		– Second summer –	
	Number	*Index*[a]	*Number*	*Index*	*Number*	*Index*	*Number*	*Index*
All:								
Salmonberry	65	3.76	65	3.20	65	2.48	66	2.51
Thimbleberry	40	1.16	35	1.63	45	.74	45	.79
Vine maple	13	2.67	10	5.00	10	3.30	10	2.90
Red alder	35	3.93	35	4.28	35	4.08	35	3.95
Red elder	70	1.81	60	2.61	70	1.78	72	2.42
Sword-fern	80	.26	80	1.38	80	.03	80	.09
Red huckleberry	25	.90	20	1.15	25	.32	25	.36
Salal	?	0	?	0	?	0	?	0
Bracken	?	1.00	20	.50	*		*	
Ocean-spray	6	1.83	6	1.83	6	.67	6	.67
Willow spp.	7	0	5	0	7	0	*	
Evergreen huckleberry	*		*		?	0	*	
Chaparral-broom	*		*		?	0	*	
Average		1.57		1.96		1.12		1.52

* = no observation; ? = damage effect observed on unrecorded number of samples.
[a] Average values based on an index from 0 for no effect to 7 for complete kill observed on designated sample shrubs.

Table 22—Damage to associated species at each area after manual cutting followed by treatment with fosamine

Area and species	Examination, number of observations, and damage rating							
	– First spring –		– First summer –		– Second spring –		– Second summer –	
	Number	*Index*[a]	*Number*	*Index*	*Number*	*Index*	*Number*	*Index*
Farmer Roundtop:								
Salmonberry	20	2.85	20	2.15	20	1.90	20	2.20
Thimbleberry	20	.80	20	.90	20	.70	20	.70
Vine maple	20	3.00	20	2.45	20	2.50	20	2.55
Red alder	15	4.73	15	4.07	20	4.70	20	3.95
Red elder	20	.75	20	1.50	20	.95	20	1.85
Sword-fern	20	0	20	0	20	0	20	0
Red huckleberry	5	1.00	5	1.20	10	1.00	10	1.20
Average		1.88		1.75		1.68		1.78
Howell Ridge:								
Salmonberry	20	4.00	20	3.55	20	3.10	20	3.70
Red elder	20	2.40	20	2.15	20	2.85	20	3.40
Sword-fern	20	0	20	0	20	0	20	0
Average		2.13		1.90		1.98		2.37
Bailey:								
Salmonberry	20	2.05	20	2.15	20	.85	20	.90
Red elder	5	1.00	5	1.60	5	.60	5	.60
Sword-fern	?	0	?	0	?	0	?	0
Salal	?	0	?	0	20	0	20	0
Evergreen huckleberry	10	0	10	0	10	.30	11	0
Average		.61		.75		.35		.30
Popo Maple:								
Salmonberry	20	2.40	20	2.40	20	1.70	20	1.80
Thimbleberry	20	.70	20	1.05	20	.85	20	.75
Red alder	1	4.00	*		3	5.67	3	6.00
Red elder	5	2.20	5	2.40	5	2.00	5	1.60
Sword-fern	20	0	20	0	20	0	20	0
Red huckleberry	10	.50	10	.40	10	.50	10	.60
Salal	?	0	?	0	?	0	?	0
Evergreen huckleberry	?	0	?	0	5	0	5	0
Chaparral-broom	10	0	10	0	10	0	10	0
Average		1.09		.78		1.19		1.19

Table 22—Damage to associated species at each area after manual cutting followed by treatment with fosamine (continued)

Area and species	Examination, number of observations, and damage rating							
	– First spring –		– First summer –		– Second spring –		– Second summer –	
	Number	*Index*[a]	*Number*	*Index*	*Number*	*Index*	*Number*	*Index*
All:								
Salmonberry	80	2.83	80	2.56	80	1.89	80	2.15
Thimbleberry	40	.75	40	.98	40	.78	40	.73
Vine maple	20	3.00	20	2.45	20	2.50	20	2.55
Red alder	16	4.37	15	4.07	23	5.19	23	4.98
Red elder	50	1.59	50	1.91	50	1.60	50	1.86
Sword-fern	60+	0	60+	0	60+	0	60+	0
Red huckleberry	15	.75	15	.80	20	.75	20	.90
Salal	?	0	?	0	20+	0	20+	0
Evergreen huckleberry	10+	0	10+	0	15	.15	16	0
Chaparral-broom	10	0	10	0	10	0	10	0
Average		1.33		1.28		1.29		1.32

* = no observation; ? = damage effect observed on unrecorded number of samples.

[a] Average values based on an index from 0 for no effect to 7 for complete kill observed on designated sample shrubs.

Table 23—Tree mortality by area, examination date, release treatment, and cause

	Trees lost, by release treatment[a, b]						
Area and date	None	Manual 1	Manual 2	Manual 3	Glyphosate	Fosamine	Manual plus fosamine
	Number						
Farmer Roundtop:							
3-81	0	0	0	0	0	0	0
5-82	0	0	1C	0	0	0	0
9-82	0	1U	3CCD	0	0	0	1S
2-84	4BBBU	0	0	0	1U	0	1S
4-85	0	0	3BSS	0	0	0	1U
2-87	0	0	0	0	0	0	2SS
Howell Ridge:							
1-81	0	0	0	0	0	0	0
10-81	2BB	0	0	0	0	2BS	3BCU
11-82	1B	1U	2BM	0	0	1B	2BC
1-84	0	0	0	0	0	0	0
4-85	0	0	0	0	0	0	0
11-86	1B	0	2MM	0	0	0	2BB
Bailey:							
1-81	0	0	0	0	0	0	0
2-82	0	0	0	0	0	0	0
3-83	0	1M	0	0	1U	0	0
1-84	0	1U	0	0	3BMS	1M	0
3-85	1U	0	0	0	0	0	0
1-87	1U	2UU	1U	0	1U	0	0
Popo Maple:							
2-81	0	0	0	0	0	0	0
2-82	0	1C	0	1B	0	0	0
10-82	0	0	0	0	0	0	0
2-84	0	0	0	2UU	0	0	0
4-85	1B	0	1U	0	0	0	1U
2-87	0	0	0	1U	0	0	0
Total:							
Number	11	7	13	4	6	4	13
Percent	5.5	3.5	6.5	2.0	3.0	2.0	6.5

[a] 50-tree sample observed per treatment at each area.
[b] Cause of mortality:
B = mountain beaver M = mechanical—J-root, snow, rolled log
C = cut in release S = spray effect
D = deer browsing U = unknown

Table 24—Average height of Douglas-firs with standard error, by treatment, year, and area

Area and treatment	Year						
	1979	1980	1981	1982	1983	1984	1986
	Centimeters						
Farmer Roundtop:							
None	70.0	118.8	156.7	195.6	243.3	293.5	428.4
Manual 1	84.3	130.3	182.2	234.3	303.3	370.6	536.1
Manual 2	88.6	120.2	149.3	179.3	220.4	269.4	412.4
Manual 3	75.1	118.6	166.3	213.3	270.3	333.4	509.2
Glyphosate	78.4	115.9	140.3	166.0	204.7	236.0	361.2
Fosamine	91.8	141.4	185.6	230.5	298.9	370.5	535.5
Manual plus fosamine	82.3	126.9	167.5	198.3	239.8	292.4	448.4
Average[a]	81.5±2.9	124.6±3.4	164.0±6.3	202.5±9.6	254.4±14.3	309.4±19.3	461.6±25.14
Howell Ridge:							
None	35.5	77.5	125.8	165.9	227.7	299.1	468.6
Manual 1	33.7	62.6	102.2	155.8	242.2	328.6	532.0
Manual 2	40.0	75.4	117.3	160.0	214.6	317.2	507.3
Manual 3	41.2	79.4	120.3	175.2	266.2	358.6	578.8
Glyphosate	32.9	63.1	97.2	148.5	234.0	321.8	520.1
Fosamine	34.1	71.9	112.9	159.4	234.7	317.1	509.3
Manual plus fosamine	38.2	74.0	103.9	112.3	159.4	208.2	348.0
Average	36.5±1.2	72.0±2.5	111.4±4.0	153.9±7.6	229.4±12.6	307.2±17.8	494.9±27.5
Bailey:							
None	44.7	86.2	142.8	208.5	270.8	312.5	383.5
Manual 1	45.1	87.5	146.6	230.5	329.6	416.3	626.2
Manual 2	54.3	92.7	147.4	221.9	311.6	397.5	613.2
Manual 3	45.2	75.4	122.2	188.6	278.0	358.9	564.3
Glyphosate	58.1	102.3	140.6	202.8	291.7	375.0	585.9
Fosamine	45.0	83.1	131.0	190.3	278.4	355.4	552.9
Manual plus fosamine	56.9	102.5	159.0	235.8	343.1	433.2	663.0
Average	49.9±2.4	90.0±3.8	141.4±4.5	211.2 ±7.1	300.5±10.6	378.4±15.5	569.8±34.2

Table 24—Average height of Douglas-firs with standard error, by treatment, year, and area (continued)

Area and treatment	Year 1979	1980	1981	1982	1983	1984	1986
	Centimeters						
Popo Maple:							
None	109.4	159.8	204.0	252.5	321.4	394.4	568.9
Manual 1	180.3	260.4	340.0	428.4	538.6	628.0	850.4
Manual 2	167.1	254.3	333.8	426.6	528.9	632.7	850.4
Manual 3	130.6	209.4	275.2	338.5	410.5	478.1	699.4
Glyphosate	128.8	190.8	243.2	301.7	386.0	467.9	659.2
Fosamine	135.2	199.9	255.0	311.3	391.8	468.4	666.5
Manual plus fosamine	146.6	224.0	288.7	359.4	452.1	548.6	751.6
Average	142.6±9.2	214.1±13.4	277.1±18.4	345.5±24.6	432.8±29.9	516.9±33.8	720.9±39.3
All locations:							
None	64.9±16.5	110.6±18.7	157.3±16.8	205.6±18.0	265.8±20.6	324.9±23.5	462.3±39.5
Manual 1	85.9±33.3	135.2±44.0	192.7±51.7	262.2±58.3	353.4±64.4	435.8±66.5	636.2±74.6
Manual 2	87.5±28.4	135.7±40.6	186.9±49.5	246.9±61.3	325.6±70.5	404.2±80.6	595.8±94.2
Manual 3	73.0±20.6	120.7±31.1	171.0±36.3	228.9±37.4	306.3±34.8	382.2±32.5	587.9±40.1
Glyphosate	74.6±20.3	118.0±26.7	155.3±31.0	204.8±34.2	279.1±40.0	350.2±48.6	531.6±63.5
Fosamine	76.5±23.2	124.1±29.5	171.1±32.0	222.9±32.9	300.9±33.1	377.8±32.2	566.1±34.7
Manual plus fosamine	81.0±23.7	131.9±32.6	179.8±39.0	226.5±51.3	298.6±63.5	370.6±75.3	552.7±93.3
Average	77.6±8.2	125.2±11.1	173.5±13.0	228.3±15.2	304.3±17.4	378.0±19.6	561.8±24.4

[a] Standard error based on variation within the individual mean.

Table 25—Average stem diameter of Douglas-firs at 30 centimeters and 1986 d.b.h. with standard error, by treatment, year, and area

Area and treatment	Stem diameter at 30 centimeters 1980	1983	1984	1986	D.b.h. 1986
	Millimeters				
Farmer Roundtop:					
None	11.3	32.3	43.8	71.5	55.3
Manual 1	15.8	50.3	63.1	93.1	70.7
Manual 2	13.0	37.6	51.0	75.3	58.0
Manual 3	14.0	45.7	62.2	88.5	67.7
Glyphosate	11.9	30.8	39.1	64.4	46.6
Fosamine	15.0	47.1	62.6	93.2	75.3
Manual plus fosamine	13.3	41.2	51.3	80.4	61.8
Average[a]	13.5±0.6	40.7±2.8	53.3±3.7	80.9±4.2	62.2±3.7
Howell Ridge:					
None	7.9	31.1	44.2	73.9	60.3
Manual 1	6.1	38.7	58.1	96.5	73.4
Manual 2	9.1	38.4	53.9	89.1	65.9
Manual 3	9.1	42.8	62.1	101.2	78.0
Glyphosate	6.3	34.7	52.9	92.2	72.3
Fosamine	7.3	34.3	54.0	93.1	72.6
Manual plus fosamine	7.2	21.7	30.0	53.4	40.7
Average	7.6±0.5	34.5±2.6	50.7±4.0	85.6±6.3	66.2±4.8
Bailey:					
None	9.3	30.5	37.9	45.5	34.7
Manual 1	12.2	61.5	80.6	127.1	92.3
Manual 2	13.2	56.2	76.4	122.7	86.6
Manual 3	9.6	49.4	72.2	115.9	80.1
Glyphosate	10.2	44.2	64.7	101.3	75.5
Fosamine	10.6	49.8	67.8	118.2	77.8
Manual plus fosamine	14.2	60.9	85.0	139.4	95.1
Average	11.3±0.7	50.4±4.1	69.2±5.9	110.0±11.6	77.4±7.7

Table 25—Average stem diameter of Douglas-firs at 30 centimeters and 1986 d.b.h. with standard error, by treatment, year, and area (continued)

Area and treatment	Stem diameter at 30 centimeters 1980	1983	1984	1986	D.b.h. 1986
	Millimeters				
Popo Maple:					
None	17.8	47.8	62.3	92.4	77.0
Manual 1	36.3	94.9	115.1	166.4	130.2
Manual 2	34.6	89.4	113.9	158.2	126.1
Manual 3	26.0	70.4	87.9	129.1	103.0
Glyphosate	22.6	60.0	79.2	116.3	90.3
Fosamine	24.1	63.1	81.6	115.1	89.8
Manual plus fosamine	29.9	76.9	95.7	131.8	105.1
Average	27.3±2.5	71.8±6.3	90.8±7.2	129.9±9.7	103.1±7.4
All locations:					
None	11.6±2.2	35.4±4.1	47.1±5.3	70.8±9.6	56.8±8.7
Manual 1	17.6±6.5	61.4±12.1	79.2±12.9	120.8±17.0	91.6±13.7
Manual 2	17.5±5.8	55.4±12.1	73.8±14.5	111.3±18.5	84.1±15.2
Manual 3	14.7±3.9	52.1±6.3	71.1±6.1	108.6±8.8	82.2±7.4
Glyphosate	12.8±3.5	42.4±6.5	59.0±8.5	93.5±10.9	71.2±9.1
Fosamine	14.2±3.7	48.6±5.9	66.5±5.8	104.9±6.8	78.9±3.8
Manual plus fosamine	16.2±4.8	50.2±12.0	65.5±15.2	101.3±20.6	75.7±14.9
Average	14.9±1.6	49.4±3.4	66.0±4.0	101.6±5.5	77.2±4.2

[a] Standard error based on variation within the individual mean.

Table 26—Costs of plantation release, by treatment

Area and cost item	None	Manual 1	Manual 2	Manual 3	Glyphosate	Fosamine	Manual plus fosamine
	Treatment						
	Dollars per acre						
Farmer Roundtop:							
Chemicals	—	—	—	—	15	27	27
Aerial application	—	—	—	—	50	50	50
Water monitoring	—	—	—	—	62	28	28
Manual 1981	—	100	100	100	—	—	100
Manual 1982	—	—	46	46	—	—	—
Manual 1983	—	—	—	65	—	—	—
Admin. and insp.	0	10	25	32	13	13	23
Howell Ridge:							
Chemicals	—	—	—	—	15	27	27
Aerial application	—	—	—	—	50	50	50
Water monitoring	—	—	—	—	62	28	28
Manual 1981	—	147	147	147	—	—	147
Manual 1982	—	—	108	108	—	—	—
Manual 1983	—	—	—	84	—	—	—
Admin. and insp.	0	10	57	82	13	13	23
Bailey:							
Chemicals	—	—	—	—	15	27	27
Aerial application	—	—	—	—	50	50	50
Water monitoring	—	—	—	—	37	37	37
Manual 1981	—	117	117	117	—	—	117
Manual 1982	—	—	90	90	—	—	—
Manual 1983	—	—	—	59	—	—	—
Admin. and insp.	0	4	14	26	18	18	22
Popo Maple:							
Chemicals	—	—	—	—	15	27	27
Aerial application	—	—	—	—	50	50	50
Water monitoring	—	—	—	—	37	37	37
Manual 1981	—	117	117	117	—	—	117
Manual 1982	—	—	85	85	—	—	—
Manual 1983	—	—	—	59	—	—	—
Admin. and insp.	0	8	19	30	18	18	26
Total	0	513	925	1247	520	500	1013
Average	0	128	231	312	130	125	253

Table 27—Shrub cover at 0.6 meter from Douglas-fir trees; averages for number of stems, diameters, heights, and areas, 1980-83

Area and year	Stems per square meter	Stem diameter: Total sample	Stem diameter: Average	Shrub height: Total sample	Shrub height: Average
	– – – Number – – –		*Centimeters*	*Number*	*Centimeters*
Farmer Roundtop:					
1980	23.9A[a]	191	1.21A	191	89.0A
1981				202	64.1A
1982				202	72.8A
1983	25.6A	160	1.16A	160	82.6A
Howell Ridge:					
1980	22.5A	155	1.02B	155	47.7B
1981				166	41.1B
1982				164	43.5C
1983	22.7A	122	1.09A	122	38.9C
Bailey:					
1980	18.4AB	174	1.03B	174	43.2B
1981				168	48.8B
1982				175	55.4BC
1983	25.3A	180	1.15A	180	59.9B
Popo Maple:					
1980	15.0B	162	1.20A	162	97.6A
1981				179	65.5A
1982				181	69.8AB
1983	32.8A	185	1.12A	186	67.3AB

[a] Means for the same attribute and year followed by the same letter do not differ significantly by Duncan's (1955) test at the 0.05 probability level.

Table 28—Shrub cover at 1.8 meters from Douglas-fir trees; averages for number of stems, diameters, heights, and areas, 1980-83

Area and year	Stems per square meter	Stem diameter: Total sample	Stem diameter: Average	Shrub height: Total sample	Shrub height: Average
	– – – – Number	*– – – –*	*Centimeters*	*Number*	*Centimeters*
Farmer Roundtop:					
1980	25.8A[a]	209	1.22A	209	89.8A
1981				218	82.8A
1982				219	84.5A
1983	28.4AB	182	1.20A	182	97.3A
Howell Ridge:					
1980	17.1B	158	1.03B	158	51.4B
1981				177	50.5B
1982				184	50.0B
1983	19.1B	133	1.11A	133	47.5C
Bailey:					
1980	18.0B	181	1.04B	181	44.9B
1981				176	55.2B
1982				190	58.2B
1983	28.1AB	190	1.13A	190	61.9BC
Popo Maple:					
1980	16.2B	169	1.24A	169	103.4A
1981				174	75.8A
1982				179	80.1A
1983	35.2A	197	1.19A	197	78.0AB

[a] Means for the same attribute and year followed by the same letter do not differ significantly by Duncan's (1955) test at the 0.05 probability level.

Table 29—Average vegetative cover around released trees in 1984 and 1986, by area and attribute

			Height of cover	
Area and year	Total cover	Adjacent cover	Dominant species	Secondary species
	– – – – *Percent* – – – –		– – – – *Centimeters* – – – –	
Farmer Roundtop:				
1984	68.7A[a]	41.1A	199A	136A
1986	87.0A	27.5A	256A	157A
Howell Ridge:				
1984	33.1B	15.5B	113A	92B
1986	47.3C	13.4A	146B	103B
Bailey:				
1984	65.7A	35.4A	201A	133A
1986	72.6B	19.4A	209AB	155A
Popo Maple:				
1984	72.5A	38.6A	199A	163A
1986	76.8B	16.6A	204AB	153A
All:				
1984	60.0	32.7	178	131
1986	70.9	19.3	204	142

[a] Attribute means for 1984 or 1986 followed by the same letter do not differ significantly by Duncan's (1955) test at the 0.05 probability level.

Table 30—Average height of Douglas-fir trees and tallest adjacent species, by treatment and year

		Release treatment													
		None		Manual 1		Manual 2		Manual 3		Glyphosate		Fosamine		Manual plus fosamine	
Species	Year	Ht.	Freq.	Ht.	Freq.	Ht.	Freq.	Ht.	Freq.	Ht.	Freq.	Ht.	Freq.	Ht.	Freq.
		Cm	*No.*	*Cm*	*No.*	*Cm*	*No.*	*Cm*	*No.*	*Cm*	*No.*	*Cm*	*No.*	*Cm*	*No.*
Douglas-fir	1980	111	200	135	200	136	200	121	200	118	200	124	200	132	200
	1981	157	198	193	199	187	199	171	199	155	200	171	198	180	197
	1982	206	197	262	196	247	194	229	199	205	199	223	197	227	194
	1983	266	193	353	195	326	194	306	197	279	195	301	196	299	193
	1984	325	191	436	195	404	190	382	197	350	195	378	196	371	191
	1986	462	189	636	193	596	187	588	196	532	194	566	196	553	187
Shrub average	1980	71	104	65	77	62	76	61	94	89	108	65	109	74	114
(on plot 0.6 m away)	1981	83	116	40	85	39	93	40	114	72	91	66	97	45	119
	1982	96	121	61	82	40	97	36	118	66	87	68	103	56	114
	1983	91	102	71	71	50	106	34	100	66	78	63	92	62	99
Dominant competitors	1984	280	191	197	194	146	189	135	197	160	191	171	194	156	184
	1986	273	189	241	193	193	187	207	196	174	194	160	196	178	187
Acer circinatum	1984	240	11	—	0	63	4	210	1	236	5	170	2	160	1
	1986	289	8	—	0	—	0	260	1	248	5	290	1	185	2
Acer macrophyllum	1984	—	0	—	0	—	0	—	0	—	0	—	0	—	0
	1986	—	0	350	1	—	0	—	0	—	0	—	0	—	0
Alnus rubra	1984	560	52	420	29	313	15	236	31	288	12	320	4	290	2
	1986	663	34	607	23	628	17	542	32	464	8	390	2	330	3
Baccharis pilularis	1984	228	4	200	1	—	0	—	0	270	1	—	0	225	2
	1986	287	3	180	1	—	0	—	0	215	2	—	0	260	2
Berberis spp.	1984	—	0	—	0	53	3	—	0	—	0	—	0	—	0
	1986	—	0	—	0	43	4	—	0	—	0	—	0	—	0
Corylus cornuta var. *californica*	1984	296	5	—	0	—	0	—	0	315	2	—	0	—	0
	1986	200	1	—	0	—	0	—	0	—	0	—	0	—	0
Gaultheria shallon	1984	—	0	90	1	69	7	58	21	92	5	70	20	69	10
	1986	125	8	180	1	84	14	79	36	115	4	89	31	95	14
Holodiscus discolor	1984	—	0	—	0	—	0	—	0	270	2	—	0	—	0
	1986	—	0	—	0	—	0	—	0	405	2	410	1	—	0
Menziesia ferruginea	1984	—	0	150	3	—	0	—	0	—	0	—	0	165	2
	1986	—	0	190	5	—	0	—	0	—	0	—	0	150	1
Picea sitchensis	1984	—	0	—	0	250	1	—	0	195	2	—	0	—	0
	1986	—	0	—	0	—	0	—	0	220	1	—	0	—	0
Polystichum munitum	1984	88	13	84	18	81	19	58	24	99	23	105	12	83	3
	1986	112	23	105	17	94	35	85	33	102	41	97	31	97	15
Prunus spp.	1984	—	0	—	0	—	0	—	0	113	3	120	1	—	0
	1986	—	0	—	0	—	0	—	0	—	0	—	0	—	0

Table 30—Average height of Douglas-fir trees and tallest adjacent species, by treatment and year (continued)

		Release treatment													
		None		Manual 1		Manual 2		Manual 3		Glyphosate		Fosamine		Manual plus fosamine	
Species	Year	Ht.	Freq.	Ht.	Freq.	Ht.	Freq.	Ht.	Freq.	Ht.	Freq.	Ht.	Freq.	Ht.	Freq.
		Cm	*No.*	*Cm*	*No.*	*Cm*	*No.*	*Cm*	*No.*	*Cm*	*No.*	*Cm*	*No.*	*Cm*	*No.*
Pseudotsuga menziesii	1984	370	1	306	5	276	5	300	6	290	4	267	10	205	4
	1986	330	1	395	6	500	2	362	6	306	5	256	9	475	2
Pteridium aquilinium	1984	—	0	173	3	—	0	—	0	—	0	—	0	—	0
	1986	—	0	207	13	164	8	120	2	163	10	145	2	153	8
Ribes sanguineum	1984	—	0	—	0	105	2	—	0	—	0	—	0	—	0
	1986	—	0	—	0	180	1	—	0	—	0	—	0	—	0
Rubus parvifolius	1984	161	38	151	18	140	23	131	28	151	41	199	31	166	44
	1986	197	41	190	26	148	22	180	29	165	35	189	30	182	44
Rubus procerus	1984	—	0	210	1	—	0	—	0	—	0	—	0	—	0
	1986	—	0	270	1	—	0	—	0	—	0	—	0	—	0
Rubus spectabilis	1984	178	59	160	102	140	97	125	74	146	52	175	58	162	96
	1986	193	65	186	94	171	78	164	54	162	67	164	72	190	91
Rubus ursinus	1984	—	0	—	0	—	0	—	0	—	0	—	0	—	0
	1986	—	0	—	0	—	0	—	0	—	0	70	1	—	0
Salix spp.	1984	—	0	—	0	—	0	—	0	—	0	—	0	—	0
	1986	—	0	380	1	—	0	—	0	203	4	247	6	—	0
Sambucus callicarpa	1984	230	5	146	8	84	8	120	10	159	32	177	47	135	17
	1986	290	2	—	0	220	2	250	1	270	1	272	6	260	1
Tsuga heterophylla	1984	—	0	300	3	—	0	310	1	—	0	—	0	—	0
	1986	—	0	300	1	—	0	600	1	—	0	—	0	—	0
Vaccinum ovatum	1984	—	0	—	0	130	1	—	0	183	3	200	6	225	2
	1986	—	0	90	1	155	2	—	0	202	6	240	3	215	2
Vaccinum parvifolium	1984	210	3	200	2	155	4	150	1	133	4	190	3	140	1
	1986	247	3	245	2	170	2	80	1	200	3	230	1	180	2

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Stein, William I. 1999. Six-year growth of Douglas-fir saplings after manual or herbicide release from coastal shrub competition. Res. Pap. PNW-RP-500. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 55 p.

Survival and growth of planted Douglas-fir (*Pseudotsuga menziesii*) saplings and associated shrubs were observed for 6 years after seven release treatments had been applied side by side on four areas in the Coast Ranges of Oregon. Four times as much Douglas-fir volume as in the control was produced by one manual cutting of shrubs, which also represented the best economic return. Diversity of competing species temporarily increased after the release treatments.

Keywords: Reforestation, Pacific Northwest, Coast Ranges, manual release, herbicide release, Douglas-fir, red alder, seedling survival, seedling growth, glyphosate, fosamine, competing vegetation, salmonberry, thimbleberry, red elder, sword-fern.

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