United States Department of Agriculture

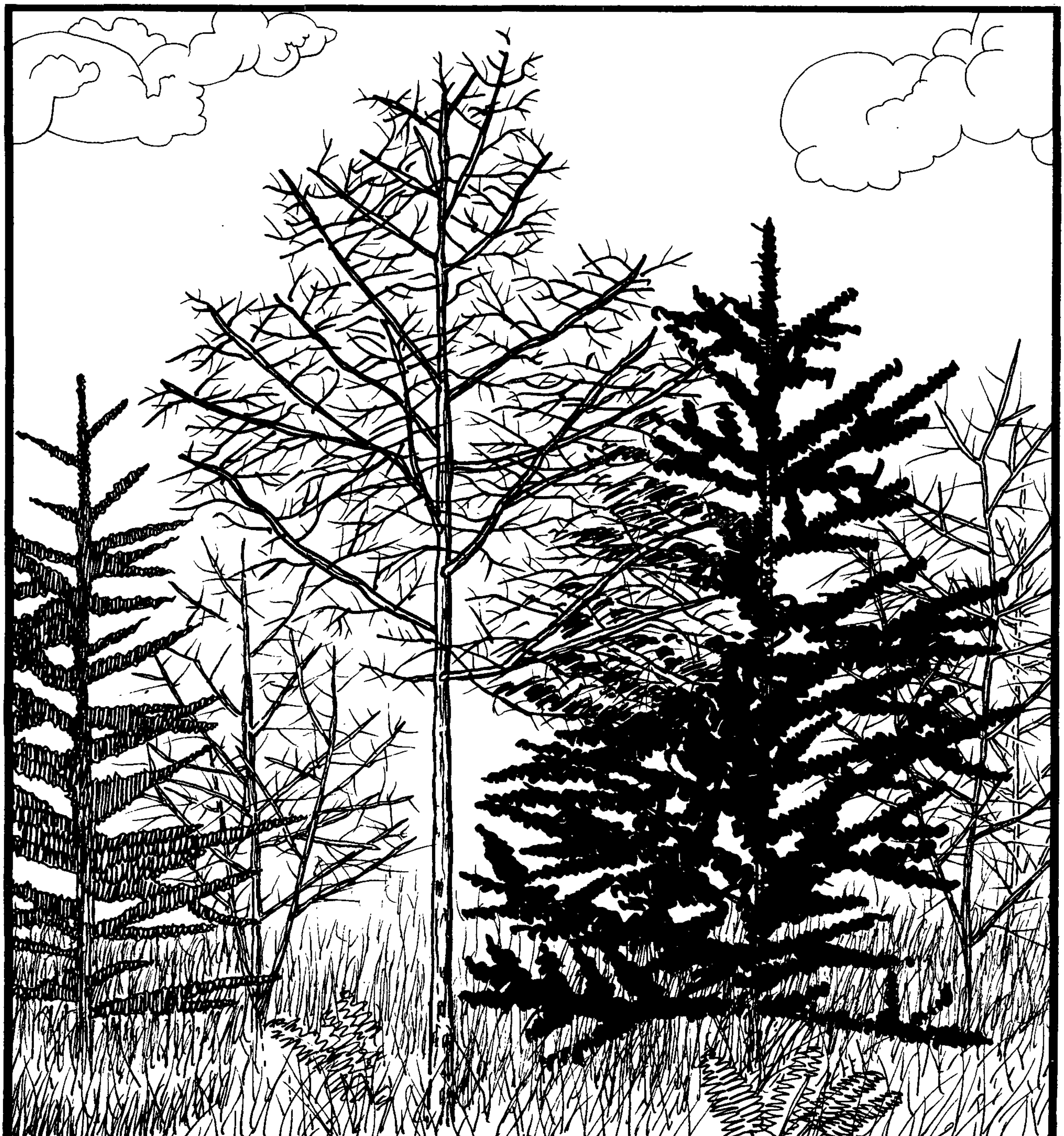
Forest Service

Pacific Northwest Research Station

Research Paper PNW-366
August 1986

Early Survival and Growth of Planted Douglas-Fir With Red Alder in Four Mixed Regimes

Marshall D. Murray and Richard E. Miller



Authors

MARSHALL D. MURRAY is a forester and RICHARD E. MILLER is principal soil scientist, Pacific Northwest Research Station, Forestry Sciences Laboratory, 3625 93d Avenue, S.W., Olympia, Washington 98502.

Abstract

Murray, Marshall D.; Miller, Richard E. Early survival and growth of planted Douglas-fir with red alder in four mixed regimes. Res. Pap. PNW-366. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station; **1986.** 13 p.

To quantify between-species interactions, we measured and compared survival and growth of planted Douglas-fir and associated planted and volunteer red alder at a location on the west side of the Cascade Range in Washington. The planted alder were wildlings dug either from a nearby area or from a distant, coastal site and interplanted into a 3-year-old Douglas-fir plantation. The volunteer alder became established in year 1; these were cut at year 3 or 7 depending on the regime tested.

The data indicated no apparent advantage in using nonlocal red alder to reduce aboveground competition with Douglas-fir at this location. Survival of both sources of interplanted alder was high, and the average diameter and height were similar through plantation age 10. Retaining about 1 100 volunteer alder per hectare (445/acre) through plantation age 7 had no measurable positive or negative effect on the associated Douglas-fir.

When alder densities are less than about 1 250/ha (500/acre), silviculturists can safely delay alder control on most average or below-average site quality land until 6 to 8 years after planting Douglas-fir. This reduces alder sprouting and permits combining complete or partial control of alder with precommercial thinning of associated Douglas-fir. To ensure timely control, periodic observations of Douglas-fir red alder mixtures are necessary, however.

Keywords: Silvicultural systems, mixed stands, competition (plant), nitrogen fixation, Douglas-fir, *Pseudotsuga menziesii,* red alder, *Alnus rubra.*

Summary

At a Douglas-fir site III location on the west side of the Cascade Range in Washington, we compared 10-year survival and growth of planted Douglas-fir in four regimes with planted or volunteer red alder. The regimes were Douglas-fir with interplanted alder wildlings of either (1) a local source or (2) a distant, coastal source; and Douglas-fir with volunteer red alder present (3) through plantation age 3 or (4) through plantation age 7.

Our purpose was to quantify between-species interactions. The data indicated no apparent advantage in using nonlocal red alder to reduce aboveground competition with Douglas-fir at this location. Survival of both sources of interplanted alder was high; their average diameter and height were similar and exceeded that of associated Douglas-fir through plantation age 10. Average percentage of sprouting stumps and average height of the tallest sprout per stump did not differ for the two alder sources.

Delaying release of Douglas-fir from volunteer alder until age 7 instead of at age 3 did not reduce Douglas-fir density nor reduce average height and diameter at breast height through plantation age 10. Retaining a heavy component of volunteer (1 100/ha) or planted (2 100/ha) red alder through plantation age 7 had no measurable positive or negative effect on the associated Douglas-fir. When density of volunteer alder is less than about 1 250/ha, silviculturists can delay alder control on most average or below-average site quality land until 6 to 8 years after planting Douglas-fir. This delayed cutting reduces alder sprouting and permits combining complete or partial control of alder with precommercial thinning of associated Douglas-fir. To balance the potential positive and negative effects of red alder in Douglas-fir plantations, control of alder density can be delayed until the upper crown of Douglas-fir crop trees is in contact with nearby alder. Periodic observations, especially during the first decade after planting, are necessary to ensure timely control.

Contents

Introduction

Red alder (*Alnus rubra* Bong.) is a commercial tree species that can provide nitrogen to improve growth of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) plantations. For example, a 2:1 mixture of red alder:Douglas-fir at the Wind River Experimental Forest, Gifford Pinchot National Forest, in southwestern Washington provided at least 40 kg $N \cdot ha^{-1} \cdot yr^{-1}$ during a 30-year period (Tarrant and Miller 1963) and markedly increased growth of planted Douglas-fir at that N-deficient site (Miller and Murray 1978, Tarrant 1961). Red alder can be established in Douglas-fir plantations through natural seeding, by concurrent interplanting, or by delayed interplanting to offset the early competitive advantage of red alder over Douglas-fir. These mixed-species systems involve sharing site resources between an N-fixing species and a principal crop species.

Using red alder as an alternative to nitrogen fertilizer does have disadvantages (Miller and Murray 1979). One major disadvantage is that early height growth of red alder exceeds that of Douglas-fir. Consequently, faster growing red alder will overtop nearby, equal-aged Douglas-fir for at least 25 years (Fowells 1965, Newton and others 1968, Miller and Murray 1978), and a large proportion of Douglas-fir may be top-damaged or die unless spacing of the two species is controlled.

Before mixed Douglas-fir/red alder plantations can be recommended as a management option for mesic sites in western Washington and Oregon, some important questions need to be answered at a number of trial locations: (1) Will interplanted red alder of a nonlocal source be less competitive with Douglas-fir than interplanted red alder of a local source? (2) When should surplus alder be cut? (3) After surplus alder are cut, what are the occurrence rate and size of alder sprouts? (4) During the various stages of plantation development, how many red alder should be admixed with Douglas-fir to provide adequate N production with an acceptable level of competition? (5) What is the comparative growth of Douglas-fir plantations that have red alder as a source of N rather than urea fertilizer?

In spring 1974, a study began at a location on the west side of the Cascade Range in Washington to answer the first question; that is, a nonlocal vs. a local source of alder.[1/] To approximate the well-documented, mixed plantation in the Wind River Experimental Forest in southwestern Washington, a 2:1 red alder:Douglas-fir mixture was established by interplanting two red alder adjacent to each Douglas-fir in a 3-year-old Douglas-fir plantation. Local red alder were interplanted on three study plots and nonlocal alder were interplanted on three others. Immediately before this interplanting, volunteer red alder were felled on these six plots and on three adjacent control plots. When the plantation was 7 years old we anticipated, however, that the 2:1 ratio would eventually result in a large proportion of dead or damaged Douglas-fir. From our earlier observations at the Wind River mixed plantation, we estimated that 50 to 100 uniformly distributed, dominant red alder per hectare would improve N and organic matter status, but would not seriously reduce Douglas-fir growing stock (Miller and Murray 1978.) Consequently, we expanded the study at White River to provide answers to the four other questions.

[1/]This study was initiated by Weyerhaeuser Company on the White River Tree Farm. It is now a cooperative study between Weyerhaeuser and the Pacific Northwest Research Station, USDA Forest Service.

This report documents stand development through Douglas-fir plantation age 10 years, when alder and Douglas-fir densities were reduced to prescribed levels and urea fertilizer was applied in one regime. We compare early survival and growth of (1) Douglas-fir in competition with either interplanted or volunteer alder, and (2) interplanted alder from two sources. Included are the number and size of alder sprouts. Future reports will update the answers to the first three questions and provide initial information on the growth of Douglas-fir with varying densities of admixed alder and with N fertilizer (questions 4 and 5).

Materials and Methods

Study Area

The study is located in a Douglas-fir plantation about 6 km east of Enumclaw, Washington, at 540 m in elevation. The moderately deep, well-drained soil of the site is Pitcher sandy loam, which developed from a mixture of volcanic ash and basaltic rock (Duncan and others 1973). Douglas-fir site index on this soil averages 33.5 m (site III) at age 50 years at breast height (Duncan and others 1973). The area had been clearcut, then logged and scarified by tractor; logging slash was piled, but not burned. The plantation was established in spring 1971 when 2 + 1 Douglas-fir seedlings were hand planted at an average density of 1 480/ha.

Treatments

Treatments were applied to twelve 0.08-ha areas. A 0.04-ha tree measurement plot was centered in each treatment area; this left a 4.1-m-wide buffer. Treatments were applied 3, 7, and 10 years after planting (table 1). At age 3, the plantation contained volunteer trees of red alder, Douglas-fir, and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.). On six plots, all volunteer alder were cut and two 2-year-old red alder wildlings were interplanted near each Douglas-fir; one at a distance of 45 cm from the Douglas-fir and the other at 90 cm. Alder from a local source (regime 1) were planted on three of the six plots, and alder from a nonlocal source near sea level (regime 2) at Aberdeen, Washington, were planted on three other plots.

Likewise on three additional plots, all volunteer alder were cut. Two years later, alder stump sprouts and new alder seedlings were cut and treated with TORDON[2] herbicide to maintain these three plots in an alder-free condition (regime 3). The three plots of regime 4 were installed 4 years after those of the other regimes.

[2] The use of trade, firm, or corporation names does not constitute an official endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others that may be suitable.

Table 1—Schedule of treatments by regime

Years after planting Douglas-fir	Regime (3 plots per regime)			
	1	2	3	4
3	All volunteer red alder cut; 2 local red alder wildlings planted adjacent to each Douglas-fir	As regime 1, but 2 nonlocal red alder wildlings planted adjacent to each Douglas-fir	All volunteer red alder cut	No treatment
5	No treatment	No treatment	Red alder sprouts and new seedlings cut; stumps treated with herbicide	No treatment
7	Most red alder cut except 50, 100, or 200/ha retained on one plot each	As regime 1	Red alder sprouts and new seedlings cut	All volunteer red alder cut
10	Douglas-fir reduced to 740/ha; new red alder sprouts and seedlings cut	As regime 1	As regimes 1 and 2	As other regimes; 224 kg N/ha as urea applied

At plantation age 7, red alder were cut from all plots. Some alder were retained on plots and buffers of regimes 1 and 2 at a density of 50, 100, or 200/ha following random assignment of these densities within each alder source. Although all alder in regimes 3 and 4 were scheduled for cutting, some were missed as determined at remeasurement 3 years later.

At plantation age 10 years, all western hemlock exceeding 1.3 m in height were cut as were surplus alder seedlings and stump sprouts (fig. 1). Douglas-fir was reduced to 740 trees/ha (300/acre) on all regimes. Average number of stems before and after cutting at ages 7 and 10 years is shown in table 2. Finally, plots of regime 4 were fertilized with 224 kg N/ha as urea.

Measurements

Tree diameters at breast height (d.b.h.) were measured at 1.3 m above ground. D.b.h. and height of Douglas-fir, hemlock, and alder were measured after the 1977 and 1980 growing seasons (plantation ages 7 and 10); height of planted Douglas-fir was also recorded after the 1973, 1974, 1975, and 1976 growing seasons.

Statistical Analyses

Analysis of variance and Tukey's Test were used to determine whether real differences existed among treatment means. These analyses were based on a completely random experiment, although the adjacent plots of regime 4 were installed 4 years after those of the other regimes. The 10-percent probability level was used to indicate statistical significance. The analysis for the 3- and 7-year data is of four treatments with three replicates of each treatment. The analysis of the 10-year data is less straightforward because the three plots in regimes 1 and 2 had differing alder densities (50, 100, and 200/ha). Although these densities were balanced within both regimes, they were not true replicates. Despite this, we treated them as replicates in our analyses.

Figure 1.—Interplanted red alder (local seed source) and associated Douglas-fir at plantation age 10 and before felling surplus conifers. A crop alder is behind the sign and 3-year-old alder sprouts are to the right; 50 alder per ha were retained at age 7 years.

Table 2—Average number of stems before removal and after removal (in parentheses) of surplus alder and conifer at plantation ages 7 and 10 years

Regime	Douglas-fir: Planted, Age 7 yr 2/	Douglas-fir: Planted, Age 10 yr	Douglas-fir: Volunteers, Age 7 yr	Hemlock, volunteers: Age 7 yr	Hemlock, volunteers: Age 10 yr	Red alder: Planted, age 7 yr	Red alder: Volunteers, age 7 yr 1/
	- - - - - -	- - - - - -	- - - - - -	Number per hectare	- - - - - -	- - - - - -	- - - - - -
Douglas-fir/planted alder:							
1. Local alder	1 095	1 070 (740)	123 (0)	239 (99)	99 (0)	1 787 (50, 100, 200) 3/	198(0)
2. Nonlocal alder	1 177	1 169 (740)	74 (0)	33 (33)	33 (0)	2 207 (50, 100, 200) 3/	165(0)
Douglas-fir/volunteer alder:							
3. Alder cut at age 3	1 243	1 218 (740)	82 (0)	288 (91)	91 (0)		280(0)
4. Alder cut at age 7	1 276	1 251 (740)	189 (0)	107 (41)	41 (0)		1 120(0)

1/ The number of volunteer alder at age 10 are shown in table 5. These alder were either missed in the cutting at age 7 or were new volunteers. All were cut at age 10.

2/ No planted Douglas-fir were cut at age 7; difference between number of stems before cutting at 10 years and at 7 years is mortality.

3/ Alder were reduced to 50/ha on 1 plot and 100 or 200/ha on the remaining plots; these crop trees were retained at age 10.

Results

Planted Douglas-Fir

Survival.—We do not know how volunteer alder affected survival and growth of Douglas-fir before plantation age 3 (equal to seedling age 6). The number of planted Douglas-fir per hectare present at age 7 and estimated survival percentage between years 3 and 7 did not vary significantly among the four regimes (table 3). Survival of Douglas-fir released from competition with 1 120/ha volunteer red alder at age 7 (regime 4) was not significantly different from survival of Douglas-fir released at age 3 (regime 3). Thus, delaying release of Douglas-fir from 1 120 volunteer alder/ha until age 7 did not reduce survival. We suspect, however, that further delay would have eliminated or damaged potential crop trees.

Growth.—D.b.h. of mean basal area (Dg) of the Douglas-fir did not vary significantly among the four regimes (table 4); thus, neither planted nor volunteer alder reduced Dg of associated Douglas-fir through plantation age 7 when surplus alder were cut. Three years later, Dg remained not significantly different among the four regimes.

Average height of Douglas-fir did not differ significantly among the four regimes at plantation age 3 when volunteer alder were cut in three regimes (table 4). Four years later, unreleased Douglas-fir in regime 4 averaged about 10 percent shorter than released Douglas-fir on regime 3, but this difference was not statistically significant. Further alder influence in regimes 3 and 4 was limited to that of 91 or 272 sprouts/ha, respectively, and of a few new volunteers (table 5). At the same time, alder influence in regimes 1 and 2 was reduced to 50, 100, or 200/ha uniformly spaced, dominant or codominant trees, plus an average of 354 or 230 sprouts/ha, respectively, as disclosed in the next inventory (table 5). Average height of Douglas-fir in regime 4 was significantly less than in regimes 1 and 2 at plantation age 7 years; by plantation age 10 years, however, average height of Douglas-fir among the four regimes did not differ significantly (table 4).

Table 3—Average number of planted Douglas-fir and red alder before cutting (at plantation ages 3 and 7 years) and survival percentage during that period

Regime	Douglas-fir			Red alder		
	Age 3	Age 7	Survival	Age 3	Age 7	Survival
	no./ha		percent	no./ha		percent
Douglas-fir/planted alder:						
1. Local alder	1 144	1 095	95.7	2 288	1 787	78.1
2. Nonlocal alder	1 226	1 177	96.0	2 452	2 207	90.0
Douglas-fir/volunteer alder						
3. Alder cut at age 3	1 284	1 243	96.8			
4. Alder cut at age 7	1 293	1 276	98.7			
Differences among regime means	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

N.S. = not significant.

Table 4—Average size of planted Douglas-fir at designated plantation ages

Regime	Dg		Height		
	Age 7	Age 10	Age 3	Age 7	Age 10
	- - mm - - -		- - - - - - m - - - -		
Douglas-fir/planted alder:					
1. Local alder	40	83	0.9	3.7b	6.4
2. Non-local alder	40	85	0.9	3.7b	6.5
Douglas-fir/volunteer alder:					
3. Alder cut at age 3	40	85	0.8	3.6ab	6.5
4. Alder cut at age 7	36	79	0.8	3.2a	5.8
Differences among regime means	N.S.	N.S.	N.S.	1/	N.S.

N.S. = not significant.

1/ Values in same vertical column with different letter are significantly different ($P < 0.10$).

Table 5—Average number of red alder stump sprouts and volunteers, and average height of tallest sprout per stump at plantation age 10 (3 years after cutting)

Regime	Stumps with sprouts		Tallest sprout	Volunteers
	no./ha	percent	m	no./ha
Douglas-fir/planted alder:				
1. Local alder	354	19	3.7b	41
2. Nonlocal alder	230	10	3.7b	74
Douglas-fir/no volunteer alder:				
3. Alder cut at age 3	91	32	4.9a	8
4. Alder cut at age 7	272	24	3.7b	16
Differences among regime means	--	N.S.	1/	--

-- = negligible; N.S. = not significant.

1/ Values in same vertical column with different letter are significantly different ($P < 0.10$).

Planted Red Alder

Survival.—Average 4-year survival percentage of interplanted alder did not vary significantly between local (78 percent) and nonlocal (90 percent) sources (table 3). An average survival of 84 percent for the two sources demonstrated that wildling red alder were successfully transplanted into this 3-year-old Douglas-fir plantation.

Growth.—Dg and average height 4 years after planting did not vary significantly between local and nonlocal sources (table 6). These initial results indicated no apparent advantage in using nonlocal red alder to reduce aboveground competition with associated Douglas-fir.

Volunteer Red Alder

Growth.—Most volunteer alder probably germinated in 1971 during the first growing season after site preparation and thus were 1 year older than the planted alder. These volunteer alder grew at an average density about half that of planted alder in regimes 1 and 2 (table 2). At plantation age 7, volunteer alder in regime 4 had a statistically significant greater Dg (23 percent) and average height (18 percent) than those of both sources of planted alder (table 6). This larger size can be explained by the 1-year difference in age and the lower density. Although fewer in number, these volunteer alder were probably more competitive because of their larger size. For example, the Douglas-fir:red alder height ratio at age 7 averaged 0.6 in regime 4 with volunteer alder as compared to 0.8 in regimes with planted alder.

Table 6—Average size of red alder at plantation age 7

Regime	Dg	Height
	mm	m
Douglas-fir/planted alder:		
1. Local alder	43a	5.0a
2. Nonlocal alder	38a	4.8a
Douglas-fir/volunteer alder:		
3. Alder cut at age 3	--	--
4. Alder cut at age 7	50b	5.8b
Differences among regime means	1/	1/

-- = not applicable.

1/ Values in same vertical column with different letter are significantly different ($P < 0.10$).

Alder Sprouts and Volunteers

Controlling alder density in Douglas-fir plantations may be difficult because of alder stump sprouts and volunteers. In this tractor-scarified study area, alder sprouts and volunteers were cut several times in unsuccessful attempts to keep regime 3 free of alder. Surplus alder were also cut in the other regimes at plantation age 7. Three years after cutting, average percentage of sprouting stumps ranged from 10 to 32 among the four regimes, but the means did not differ significantly (table 5). Average sprouting percentage (32) and average height (4.9 m) of the tallest sprout from each stump after 3 years were greatest from the few, unwanted alder in regime 3, probably because these sprouts were from younger trees that survived earlier cuttings.

Average height of the tallest, 3-year-old sprout per stump in regimes 1, 2 (planted alder), and 4 (volunteer) were the same. The associated Douglas-fir were taller than these alder sprouts and averaged between 5.8 and 6.5 m (fig. 2); thus, cutting surplus alder at age 7 years reduced the risk of upper crown abrasion but did not completely eliminate alder root competition or N contributions.

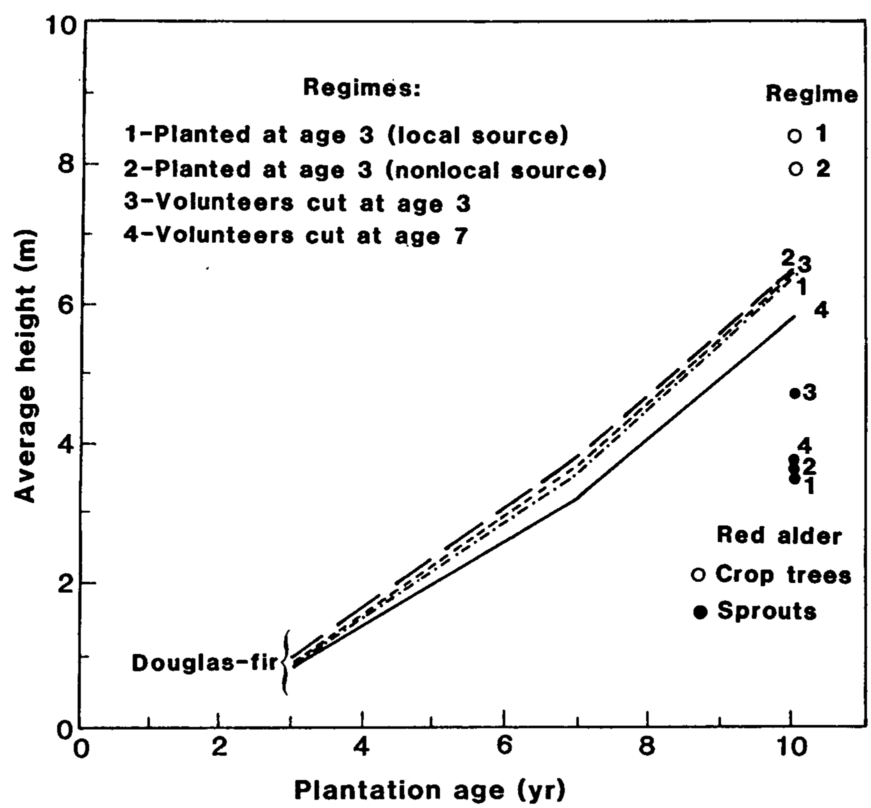


Figure 2.—Trend of average height of planted Douglas-fir and average height of crop trees and sprouts, both at plantation age 10 years, by regime.

Discussion

Local vs. Nonlocal Interplanted Alder (Question 1)

Our data indicated no apparent advantage in using nonlocal red alder to reduce aboveground competition with Douglas-fir at this location. Survival of both sources of planted alder was high and comparable (table 3).

Cole (1984) also documents good survival of red alder wildlings planted at three forest locations in Oregon; two of these locations were abandoned pastures. All locations were below 200 m elevation. Local sources of 1-year-old alder wildlings were transplanted at each location and herbaceous vegetation controlled by herbicide during the first 2 years after planting. These locations were selected to sample a transect of climates: the warm, dry climate of the Willamette Valley; the warm, moist climate of the mid-Coast Ranges; and the cool, moist climate of the coastal fog belt. Red alder survival in the 5-year period after planting was high at all locations. Survival averaged nearly 90 percent; practically all mortality occurred in the first year. Vigor of transplanted alder was reduced (1) by a late spring frost that top-killed most alder at the mid-Coast Ranges location, (2) by deer and elk browsing and rubbing at two locations, and (3) by low vigor and early leaf senescence at the coastal site that did not occur in volunteer alder.

We had anticipated that nonlocal, coastal alder would have lower survival and slower growth than a local source from near this 540-m elevation. Nonlocal alder seedlings from a source close to sea level that were interplanted in a 4-year-old Douglas-fir plantation at 600 m in the Wind River Experimental Forest were severely frosted the first autumn and spring after planting; yet local, volunteer alder were not damaged (Miller and Murray 1978). In contrast, our coastal source of red alder was not damaged by the below-freezing air temperatures that occur between November and April at the White River Tree Farm.

Average percentage of sprouting stumps and average height of the tallest sprout did not differ for the two alder sources. Moreover, the number and size of associated Douglas-fir through plantation age 10 provided no basis for preferring either alder source.

At this location with an average volunteer alder density of 1 120/ha and an average red alder:Douglas-fir density ratio of about 1:1, delayed cutting of volunteer alder until year 7 did not reduce the number of Douglas-fir available for crop tree selection. Although average height and Dg of Douglas-fir in the volunteer alder plots (regime 4) were about 10 percent less than those of Douglas-fir released at 3 instead of 7 years, our statistical analyses indicated that this difference was not significant.

Cutting Surplus Volunteer Alder (Question 2)

We believe that further delay of release would have reduced Douglas-fir survival and increased damage of crop trees through mechanical abrasion of buds and twigs. For example, our height class frequency data showed that regimes 3 and 4 had similar ranges of Douglas-fir heights, but the delayed release plots (regime 4) had a larger proportion of trees in the shorter height classes (46 vs. 31 percent were shorter than 4 m at age 7). As expected, these short, spindly trees were typically located under clumps of alder with closed canopy.

For naturally seeded red alder stands, and at elevations below 150 m on Douglas-fir sites I and II in southwest Washington, Dougherty[3/] projected crown closure at 2 to 6 years from seed depending on alder density. For 1 250 alder/ha, he projected canopy closure at 6 years. Severe competition for light between alder and associated Douglas-fir would start at that time. Considering the lower site quality and lower alder density in our regime 4, one could reasonably expect crown closure and strong competition between Douglas-fir and red alder to occur after 6 years at the White River site.

Based on our data from White River and Dougherty's projections for higher site lands, alder control can safely be delayed on most Douglas-fir site III or poorer land until 6 to 8 years after planting Douglas-fir, if alder density is less than 1 250/ha. This could permit combining alder control with precommercial thinning of Douglas-fir and, thus, eliminate earlier spraying or mechanical release. A specific number of well-spaced alder could be left during the thinning operation to provide nitrogen.

Size and Occurrence of Sprouts (Question 3)

Three years after the release cutting in February at plantation age 7, from 0 to 46 percent of the alder stumps on the 12 plots had sprouts. Treatment means ranged from 10 to 32 percent, but these did not differ significantly. The most frequent sprouting and the tallest sprouts occurred in "alder-free" regime 3. Because of two earlier attempts to eradicate alder from this regime, alder seedlings cut at plantation age 7 were undoubtedly younger than those of the other regimes. Mineral soil exposed during scarification undoubtedly favored continued natural regeneration by providing favorable conditions for alder germination and survival (Kenady 1978, Newton and others 1968).

Recent research (Harrington 1984) shows that red alder sprouting is most vigorous in 1- to 2-year-old trees and less so in trees 3 to 10 years old at the time of cutting. Because cutting red alder at an early age leaves a stump conducive to sprouting, mechanical release of Douglas-fir from competing alder could be delayed until Douglas-fir crop trees are clearly threatened. Stump sprouting can also be minimized by cutting during the growing season (vs. our cutting before the growing season) and by leaving a low stump of less than 10 cm (Harrington 1984).

Without further control, vigorous alder sprouts could again overtop Douglas-fir (a negative effect) yet provide additional N-rich organic matter (a positive effect). To obtain a desirable balance between the positive and negative effects of red alder sprouts or seedlings in Douglas-fir plantations, silviculturists must systematically control alder density, especially in the first decade.

3/ Unpublished report, 1980, "Relationship of Alder Stand Characteristics to the Rate of Crown Closure," by P.M. Dougherty, Weyerhaeuser Company, Western Forestry Research Center, Centralia, WA. Report is on file at the Forestry Sciences Laboratory, 3625 93d Avenue, S.W., Olympia, WA 98502.

Among the regimes that we tested, regime 3 probably had the least potential for influencing Douglas-fir— either positively or negatively. Although regime 3 was designed to be a control, it was not free of alder because (1) this regime probably had a similar number of N-fixing alder volunteers through age 3 as the other regimes (table 3) and (2) alder sprouts and additional volunteers remained despite repeated efforts to maintain an alder-free condition (tables 2 and 5). Both facts compromised regime 3 as a control treatment. Despite a lesser alder component, average 7- and 10-year height and diameter of Douglas-fir in regime 3 did not differ from height and diameter in the remaining regimes that had greater densities of alder. These results have several possible explanations:

1. Available nitrogen may not limit growth of Douglas-fir at this site—at least in the early stage of plantation development.

2. Retaining alder for more than 3 years after planting Douglas-fir may have no additional or measurable impact at this location.

3. The negative, competitive effects of red alder may have offset the positive effects of N additions after age 3 at this site.

Future measurements should be enlightening for several reasons. First, the plantation's need for nitrogen is likely to peak about the time of canopy closure; thus, N shortages are more likely to limit growth in the immediate future in regime 3. Second, the positive effects of the alder in regimes 1 and 2 (with 50, 100, or 200 alder/ha) should become evident. Finally, we shall have the opportunity to compare the growth of Douglas-fir fertilized with urea (regime 4) to that of Douglas-fir with a specified number of admixed alder.

Conclusions

1. Several conclusions can be drawn from this study: Both a local and a nonlocal source of wildling red alder were successfully interplanted into this 3-year-old Douglas-fir plantation. Survival percentage 4 years after planting did not vary between local and nonlocal sources of alder, and neither Dg nor average height differed between the two sources. Our data indicated no apparent advantage in using nonlocal red alder to reduce aboveground competition with Douglas-fir at this location.

2. Seven-year-old, volunteer alder, which were 1 year older and growing at 50-percent lower density than the interplanted alder, were an average of 23 percent larger in diameter and 18 percent taller than interplanted alder. Cutting these volunteer alder at plantation age 7, instead of at age 3, did not affect Douglas-fir survival or average size. Further delay probably would have eliminated or damaged some crop trees.

3. Alder competition at average densities of 1 100-2 200 alder/ha did not affect Douglas-fir survival or average tree size at plantation age 7 years; average number, Dq, and height of planted Douglas-fir in the three regimes with competing alder (both planted and volunteer) were not different from those in regime 3 with only a few, unwanted alder seedlings and sprouts.

4. When red alder densities are lower than about 1 250/ha, silviculturists can delay alder control on site III or lower until 6 to 8 years after planting Douglas-fir. This will reduce sprouting and permit combining complete or partial control of alder with early precommercial thinning. Thus, earlier chemical or mechanical release can be eliminated.

5. Three years after cutting alder in February (at plantation age 7 years), 10 to 32 percent of alder stumps in the regimes we studied had sprouts. Average height of the tallest sprout per stump ranged from 3.7 to 4.9 m among the four regimes (vs. 5.8 to 6.5 m for associated Douglas-fir). Without control, these sprouts may provide future positive (N-addition) or negative (crown competition) effects. To further minimize sprouting, alder should be cut close to the ground and cut during the growing season.

6. To obtain a desirable balance between positive and negative effects of red alder in Douglas-fir plantations, control of alder density should be delayed until the upper crown of Douglas-fir crop trees is in contact with nearby alder. Periodic observations, especially during the first decade after planting, are necessary to ensure timely control.

7. Because of some recurring alder sprouts and volunteers, our control regime was not truly free of alder. Our finding no difference in average size of planted Douglas-fir in this regime vs. the others is, therefore, not a pure demonstration that alder failed to affect growth of Douglas-fir. Measurable positive benefits of N-fixation by alder are most likely at future crown closure when demand for this nutrient is greater.

Acknowledgments

We thank the following for their help: Weyerhaeuser Co. for providing the study area and financial and technical support; John Hazard and Tim Max for guidance in experimental design and analysis; and Jim Wilcox for statistical analyses.

English Equivalents

1 centimeter (cm) = 0.3937 inch
1 meter (m) = 3.2808 feet
1 hectare (ha) = 2.4711 acres
1 kilogram (kg) = 2.2046 pounds

Literature Cited

Cole, Elizabeth C. Fifth-year growth and response of Douglas-fir to crowding and other competition. Corvallis, OR: Oregon State University; **1984.** 321 p. M.S. thesis.

Duncan, S.H.; Webster S.R.; Steinbrenner, E.C. Soil survey of the White River Tree Farm. Centralia, WA: Weyerhaeuser Company, Forestry Research Center; **1973.** 19 p. and maps.

Fowells, H.A., comp. Silvics of forest trees of the United States. Agric. Handb. 271. Washington, DC: U.S. Department of Agriculture; **1965.** 762 p.

Harrington, C.A. Factors influencing initial sprouting of red alder. Canadian Journal of Forest Research. 14: 357-361; **1984.**

Kenady, R.M. Regeneration of red alder. In: Briggs, D.G.; DeBell, D.S.; Atkinson, W.A., comps. Utilization and management of alder. Gen. Tech. Rep. PNW-70. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; **1978:** 183-191.

Miller, R.E.; Murray, M.D. The effects of red alder on growth of Douglas-fir. In: Briggs, D.G.; DeBell, D.S.; Atkinson, W.A., comps. Utilization and management of alder. Gen. Tech. Rep. PNW-70. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; **1978:** 283-306.

Miller, R.E.; Murray, M.D. Fertilizer versus red alder for adding nitrogen to Douglas-fir forests of the Pacific Northwest. In: Gordon, J.C.; Wheeler, C.T.; Perry, D.A., eds. Symbiotic nitrogen fixation in the management of temperate forests. Corvallis, OR: Oregon State University; **1979:** 356-373.

Newton, M.; El Hassan, B.A.; Zavitkovski, J. Role of red alder in western Oregon forest succession. In: Trappe, J.M.; Franklin, J.F.; Tarrant, R.F.; Hansen, G.M., eds. Biology of alder. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; **1968:** 73-74.

Tarrant, Robert F. Stand development and soil fertility in a Douglas-fir-red alder plantation. Forest Science 7: 238-246; **1961.**

Tarrant, Robert F.; Miller, Richard E. Accumulation of organic matter and soil nitrogen beneath a plantation of red alder and Douglas-fir. Soil Science Society of America Proceedings. 27: 231-234; **1963.**

The **Forest Service** of the U.S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

The U.S. Department of Agriculture is an Equal Opportunity Employer. Applicants for all Department programs will be given equal consideration without regard to age, race, color, sex, religion, or national origin.

Pacific Northwest Research Station
319 S.W. Pine St.
P.O. Box 3890
Portland, Oregon 97208

Murray, Marshall D.; Miller, Richard E. Early survival and growth of planted Douglas-fir with red alder in four mixed regimes. Res. Pap. PNW-366. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station; **1986.** 13 p.

To quantify between-species interactions, we measured and compared survival and growth of planted Douglas-fir and associated planted and volunteer red alder at a location on the west side of the Cascade Range in Washington. The planted alder were wildlings dug either from a nearby area or from a distant, coastal site and interplanted into a 3-year-old Douglas-fir plantation. The volunteer alder became established in year 1; these were cut at year 3 or 7 depending on the regime tested.

The data indicated no apparent advantage in using nonlocal red alder to reduce aboveground competition with Douglas-fir at this location. Survival of both sources of interplanted alder was high and the average diameter and height were similar through plantation age 10. Retaining about 1 100 volunteer alder per hectare (445/acre) through plantation age 7 had no measurable positive or negative effect on the associated Douglas-fir.

When alder densities are less than about 1 250/ha (500/acre), silviculturists can safely delay alder control on most average or below-average site quality land until 6 to 8 years after planting Douglas-fir. This reduces alder sprouting and permits combining complete or partial control of alder with precommercial thinning of associated Douglas-fir. To ensure timely control, periodic observations of Douglas-fir red alder mixtures are necessary, however.

Keywords: Silvicultural systems, mixed stands, competition (plant), nitrogen fixation, Douglas-fir, *Pseudotsuga menziesii,* red alder, *Alnus Rubra.*

U.S. Department of Agriculture
Pacific Northwest Research Station
319 S.W. Pine Street
P.O. Box 3890
Portland, Oregon 97208

BULK RATE
POSTAGE +
FEES PAID
USDA-FS
PERMIT No. G

Official Business
Penalty for Private Use, $300

do NOT detach label