United States
Department
of Agriculture
Forest Service

**Pacific Southwest
Research Station**

Research Paper
PSW-RP-246

Timing and Duration of Release Treatments Affect Vegetation Development in a Young California White Fir Plantation

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Publisher

Albany, California
Mailing address:
PO Box 245, Berkeley CA
94701-0245

(510) 559-6300

http://www.psw.fs.fed.us

March 2001

Pacific Southwest Research Station

Forest Service
U.S. Department of Agriculture

Abstract

McDonald, Philip M.; Fiddler, Gary O. 2001. **Timing and duration of release treatments affect vegetation development in a young California white fir plantation.** Res. Paper PSW-RP-246. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 14 p.

The density and development of snowbrush, greenleaf manzanita, goldenbush (rabbitbrush), and graminoids were evaluated in a young California white fir plantation in northern California from 1986 through 1995. Manual grubbing and an herbicide created treatment regimes that lasted for 3 to 6 years and vegetation recovery times of 4 to 10 years. The timing and duration of the grubbing and spraying operations constituted the treatments. In terms of foliar cover and height, snowbrush was the most vigorous shrub species. By the end of the study it had more foliar cover (16,350 ft^2 per acre) in the control than all the other species combined and had the greatest height (2.9 feet). It also was significantly wider and taller in the control than in any other treatment. California white fir survival and height, diameter, and foliar cover growth were all enhanced by early release. Releasing every year for the first 3 years and for the first 6 years after planting were significantly effective treatments. However, treating for the first 6 years had no significant advantage over treating for the first 3 years. Delaying treatment for 3 years and then treating each year for years 4 through 6 gave no significant growth advantage over seedlings in the control. For white fir seedlings in the control, their foliar cover was less than that of the shrubs and graminoids, and their average height was less than that of snowbrush. Increased mortality and lower growth for these seedlings are likely. Early release was effective because it kept the competing shrubs and graminoids from recovering from the effects of site preparation, providing needed site resources to the white fir seedlings.

Retrieval Terms: competing vegetation, northern California, plant succession, white fir seedlings, timing of release

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In Brief. . .

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Shrinking budgets and a lack of resources have often caused the treatment of competing vegetation in young conifer plantations to be postponed, sometimes for two or three growing seasons or even longer. At such times, forest vegetation managers wonder: "Where did all that grass and all those shrubs come from?" "What will they do to the growth of my conifer seedlings?"

Grass and shrubs are normal in most plantations in California, especially on poorer sites at higher elevations. In this 1986 to 1995 study with planted California white fir seedlings, which was on a poor site at the 5,600-foot elevation, the original plant community was one of mature shrubs and a few forbs and graminoids (grasses plus sedges) with no conifers. After site preparation (crush and burn), most of the original species reappeared from root-crown sprouts (shrubs), from dormant seeds in the soil (shrubs, some graminoids), and from windblown seeds (graminoids, forbs). A total of 16 species were found in treated plots and control during the 10-year study, which ranked it last (range was 17 to 46 species) in terms of species richness in our National Forest Service Administrative Study on alternative release methods.

This study differs somewhat from most studies that evaluate alternatives for controlling competing vegetation in young conifer plantations. We wished to document the recovery of the vegetation after a series of manipulations that were applied at different times and continued for several durations. We hypothesized that the amount of vegetation and when it was present, relative to site preparation and release, would affect the various species in the community and in turn affect the conifer seedlings. Thus, the manual grubbing and herbicide that we applied served only to accomplish the treatments. The different timings and durations were the treatments. These were:

- Treat first 6 years (1986-1991), develop naturally last 4 years: **T-first-6**;
- Treat first 3 years (1986-1988), develop naturally last 7 years: **T-first-3**;
- Delay 3 years, treat next 3 years (1989-1991), develop naturally last 4 years: **T-second-3**;
- No treatment after site preparation, develop naturally entire 10 years of the study (1986-1995): **Control**.

Colonization, as quantified in the control, was rapid. After one growing season, the number of snowbrush plants was 6,350 per acre; greenleaf manzanita, 4,350 per acre; goldenbush, 450 per acre; and graminoids 1,700 plants per acre. By the study's end, similar values were snowbrush, 3,500 plants per acre; greenleaf manzanita, 10,900 plants per acre; goldenbush, 17,400 plants per acre; and graminoids, 65,050 plants per acre. Foliar cover was greatest by far for snowbrush, which by the end of the study, was 16,350 ft^2 per acre. Average height at the study's end ranged from 1.1 feet for goldenbush to 2.9 feet for snowbrush.

Among treatments, average density and foliar cover values were generally higher in the control for the three shrub species, but lower for the graminoids. Average height tended to be highest in the control for snowbrush and greenleaf manzanita, but intermediate for goldenbush and the graminoids.

Time since disturbance, or time for the competing vegetation to recover, often is cited as being important. But in this study, not giving the competing species in the community time to recover was the key. Early release—that applied soon after planting—was the most effective treatment. For white fir seedlings, applying it for the first 3 years resulted in statistically significant increases in survival and average growth (height, diameter, foliar cover) relative to the control. Continuous early treatment for 6 years also was effective, but no more so, at least for stem height, than releasing for the first 3 years. On the basis of worker's comments, it was also more expensive. Delaying treatment for the first 3 years and then treating each year for years 4 through 6 produced average white fir height, diameter, and foliar cover values that did not differ significantly from those in the control. Just site preparation alone, as in the control, produced white fir seedlings that had less foliar cover than that of shrubs and graminoids and were shorter than snowbrush plants. On the basis of data and graphs, survival of white fir seedlings in the control is threatened, and loss of growth relative to the early treatments is almost certain.

The forest land manager now has some idea of the species that develop in a young white fir plantation on a poor site, and their density, development, and competitive potential relative to various timings and durations of treatment. Survival and growth of planted California white fir seedlings also are indicated, as well as statistical differentiation among treatments. Ecologically, the data presented in this study show species richness and early succession in this plant community.

Introduction

Of the six major conifer species in plantations in the Sierra Nevada and southern Cascades of California, the response of white fir (*Abies concolor* var. *lowiana* [Gord.] Lemm.) and incense-cedar (*Libocedrus decurrens* Torr.) to vegetation management has received the least amount of study. On the basis of observation and limited data, several authors (Hunt 1963, Laacke and Fiske 1983) have stated the need for manipulating competing vegetation to enhance seedling survival and growth, and one author (Gordon 1970) noted that competing vegetation had virtually eliminated natural white fir seedlings in an area that had been "adequately" stocked initially. Fitzgerald and others (1991) recommended that new studies be conducted on ways to increase the field survival of tree species that had low survival rates, such as white fir. On a larger scale, Rundel and others (1977) stated that quantitative data for white fir communities in the montane forest zone of California, other than in giant sequoia (*Sequoiadendron giganteum* [Lindl.] Buchholz) groves, were fragmentary.

Research in northern and central California on ponderosa pine (*Pinus ponderosa* Dougl. ex Laws. var. *ponderosa*) and Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) has shown that release from competing vegetation the first year is critical, and that release during the first 3 years is worthwhile (Fiddler and McDonald 1987, McDonald and Fiddler 1989).

However, release after 3 years generally is not cost-effective. This is because the invading shrubs, forbs, and grasses invade rapidly, are diverse and dense, often grow faster than the newly planted conifer seedlings, and deny site resources to them. On the basis of information from 32 logged areas at higher elevations in northern and central California, Gordon and Bowen (1978) found that time since disturbance (site preparation) influenced the composition and development of the plant community. After one complete growing season, an average of 50 percent of the sample locations suitable for plants were already occupied. On a higher quality site at a lower elevation, McDonald (1999) noted that almost all of the habitable microsites were occupied by invading vegetation after five growing seasons. Results from many studies in plantations in northern and central California show that the number of plant species in new plantations range from 17 to 41 (McDonald and Fiddler 1993) and the number of plants from about 15,000 (McDonald and Abbott 1997) to more than 150,000 per acre (McDonald and others 1996), especially if grasses and forbs are well represented. Many shrubs and grasses are better adapted than the nursery-grown pines and firs and have faster-developing and more massive root systems (Jackson 1985, Logan 1983, McDonald 1982, McDonald and Fiddler 1989, Mooney and Dunn 1970). Consequently, they reach a zone of adequate soil moisture first, use the moisture, and deny it to the conifer seedlings.

Not only does delayed release have a biological cost, it has an economic component as well. Many studies have shown that manually releasing conifer seedlings in 4-year and older vegetation costs more than releasing them from 1- to 3-year-old vegetation. On a poor site in northern California, for example, manually grubbing vegetation each year for years 4 through 6 was two and one-half times more expensive than treating it each year for the first 3 years (McDonald and Fiddler 2001).

Plainly, competition must be controlled, but knowledge on when and how to release young California white fir seedlings is lacking. Will early release benefit white fir as it did for ponderosa pine and Douglas-fir? Will release after 3 years be ineffective as well? Information on growth of seedlings of this species in released and unreleased plantations also is lacking.

As part of a National Forest Service administrative study on alternative release methods (Fiddler and McDonald 1984), data were gathered from 1986 through 1995 on vegetation developing after site preparation in a control and on vegetation manipulated deliberately by grubbing and applying a herbicide to create different timespans. The timespans, or more specifically "vegetation recovery times after disturbance by site preparation and release," are the treatments.

This paper reports the recovery of the plant community relative to the timing and duration of the treatments, and it quantifies the survival and growth of California white fir seedlings after immediate and delayed release.

Methods

Location and Site Characteristics

The study area, located on land owned by Sierra Pacific Industries in the southern Cascade mountains, is about 25 airline miles northeast of McCloud, California. Vegetation in the area has been placed in the montane and subalpine region of the Sierra Nevada and Cascade Ranges by Rundel and others (1977) and in the white fir forest vegetation type (Gordon 1980). Before the study began, the area was a brushfield, and probably had been for at least 50 years. It had not always been a brushfield, however, as an occasional blackened stump and log in the study area indicated that it had once supported trees. The forest stand then probably was much like that in the nearby forest today. California white fir is the dominant species, with California red fir *(Abies magnifica* A. Murr.) second. Sierra lodgepole pine (*Pinus contorta* var. *murrayana* [Grev. & Balf.] Engelm.) and incense-cedar are occasional species along with willow (*Salix* spp.).

The mature brushfield consisted of 4- to 5-foot tall plants of snowbrush (*Ceanothus velutinus* Hook. var. *velutinus*), bitter cherry (*Prunus emarginata* [Hook.] Walp.), and greenleaf manzanita (*Arctostaphylos patula* E. Greene). Goldenbush (*Ericameria bloomeri* [A. Gray] J.F. Macbr.) [= *Haplopappus bloomeri* A. Gray] (Hickman 1993) was scattered throughout and most abundant in small openings.

Site quality of the study area is medium-poor with height of dominant California white fir averaging about 60 feet in 50 years (Biging and Wensel 1984). The soil, which is closely related to the Avis series, is an ashy-skeletal, frigid Dystric Xerorthent. It was formed from volcanic ash, usually deposted over and in fractured lava flow rock. It has a stony, sandy-loam texture and is about 5 feet deep. Stones, gravel, and sand are abundant throughout. The elevation is about 5,600 feet, the slope is 5 percent, and the aspect is east. The area is remarkably uniform with respect to slope, aspect, and soil. Precipitation averages about 55 inches per year, with about 80 percent falling as snow. Temperatures range from 20 °F to 80 °F with the average annual temperature being 43 °F. The growing season is about 100 days.

Site-preparation was by tractor crushing of brush in spring 1985 and burning the dead brush with a helitorch in fall 1985. Only blackened stubs of the largest shrub clumps remained.

Container-grown California white fir seedlings were raised in the Ben Lomand Nursery and outplanted as plugs in spring 1986. Spacing was 8 by 8 feet. Survival of seedlings in all study plots at the end of the first growing season was 92 percent.

The plant community when the study began consisted of sprouts from shrub root crowns, plants from dormant seeds in the soil, and plants from windblown seeds. In addition to the planted white fir seedlings, the early plant community consisted of the same species of shrubs noted earlier, plus a few grasses and forbs. Several animals were present in the study area, especially deer (*Hemionus* spp.) and ground squirrels (*Spermophilus* spp.). Rabbits (*Lepus* spp.) were only occasionally seen, and pocket gopher (*Thomomys* spp.) mounds were scarce in spite of the forbs and grasses.

Study and Design

The experimental design was completely randomized with one-way treatment structure. Four treatments, including the control, were each replicated four times. A replicate (plot) was rectangular and consisted of about 0.14 acre on which were at least 45 California white fir seedlings surrounded by one or two rows of buffer (seedlings receiving similar treatment). The study began in 1986 and ended in 1995. Treatments and treatment dates were:

- Treat first 6 years (1986-1991), develop naturally last 4 years: **T-first-6**;
- Treat first 3 years (1986-1988), develop naturally last 7 years: **T-first-3**;
- Delay 3 years, treat next 3 years (1989-1991), develop naturally last 4 years: **T-second-3**;
- No treatment after site preparation, develop naturally entire 10 years of the study (1986-1995): **Control**.

Plots in the T-first-6 and T-first-3 treatments were treated by applying an herbicide to the entire plot plus the buffer in 1986 and 1987 and then grubbing to a 5-foot radius thereafter as needed. Plots in the T-second-3 treatments were grubbed to a 5-foot radius. Vegetation was grubbed below the root crown with hand tools. The herbicide (Roundup)[1] (2 and 5 percent solutions) was applied directly with a backpack apparatus according to recommendations on the label. Spraying took place between 7 a.m. and 9 a.m. PST on clear days with little or no wind. A guide was used to ensure uniform coverage of the herbicide and to avoid overlapping and skipped areas. Crowns of entire plants were sprayed until wet. Plastic bags were used to cover the white fir seedlings.

Grubbing and spraying were performed during the summer at a time when growth of the white fir seedlings had ceased but that of the shrubs was continuing.

Sampling

Of the 45 California white fir seedlings in each plot, 30 that appeared to have good potential of becoming harvestable trees were selected and tagged. Chlorotic and misshapen seedlings that would be removed in the first precommercial thinning were excluded. Stem diameter (measured at 12 inches above mean groundline) and height were measured on each. The seedlings were periodically checked for injury from the herbicide, animals, and insects.

Sampling intensity for evaluating other vegetation was five randomly selected subplots in each plot. Subplots were square and centered around white fir seedlings and encompassed 1 milacre (0.001 acre or 43.56 ft^2). The most abundant species were evaluated for density, foliar cover (the sum of shadows that would be cast by leaves and stems of individual species expressed as a percentage of the land surface [Daubenmire 1968]), and average dominant height (average of the three tallest stems measured from mean ground line to bud). More specifically, number of plants in each subplot was counted, foliar cover was visually estimated, and height was measured with a graduated pole.

To test for treatment effects and significant differences among treatments, one-way analysis of variance of treatment means (fixed effect model; Steel and Torrie 1980) and Tukey tests were applied (SAS Institute Inc. 1988). Statistical significance in all tests was at $\alpha = 0.05$. Data were gathered from permanent plots measured each year, and where analyses of means from repeated measurements are concerned, the data are not truly independent. The α levels or type I errors given for various tests apply to each measurement period and year separately. In some data sets, the variance may not be equal among treatments each year.

To quantify plant diversity, all species were noted on study plots when the study began and when it ended.

[1]This paper neither recommends the pesticide uses reported nor implies that the pesticides have been registered by the appropriate governmental agencies.

Results

Plant Diversity

The natural plant community on all plots near the beginning of the study in 1986 consisted of no conifer species, 6 species of shrubs, 4 forbs, and 2 graminoids (grasses plus sedges) (*table 1*). By the end of the study, vegetation in the study plots included a few natural seedlings of California white fir, 5 shrubs, 6 forbs, and 3 graminoids for a total of 15 species. One species of shrub, bush chinquapin (*Chrysolepis sempervirens* [Kellogg] Hjelmq.), noted initially, could not be found at the end of the study. No other species were missing when the study ended. One species (*Gayophytum*) was prevalent on plots early in the study and then became scarce, and one species (*Monardella*) was scarce when the study began and became quite abundant when the study ended.

Snowbrush

Because it originated both from sprouts and seed, snowbrush was the dominant shrub species in the plantation in 1986 in terms of average density and foliar cover. Diary records in 1986 and 1987 indicated that many new snowbrush seedlings were becoming established in recently disturbed plots, and that growth, particularly of sprouts, was vigorous. Snowbrush also dominated in 1995 in terms of average foliar cover and height. Snowbrush was lightly browsed in 1988, heavily browsed in 1989, and lightly browsed in 1990.

Average density of snowbrush in the control was 6,350 plants per acre in 1986, which was peak density, and then steadily declined to 3,500 plants per acre at the end of the study in 1995 (*table 2*). Foliar cover and height of snowbrush increased steadily throughout the study and reached 16,350 ft^2 per acre and 2.9 feet tall, respectively. For the 10 years of the study, the average number of snowbrush plants in the control decreased 45 percent, foliar cover increased more than 17 times, and height increased more than 7 times (*table 2*).

Among treatments, plots that had no disturbance after site preparation, as in the control, had the most plants at the end of the study, and significantly more density, foliar cover, and height than counterparts in other treatments (*table 3*).

Table 1—*Natural vegetation in study plots, 1986-1995*

Species	1986	1995
Conifers		
Abies concolor	—	X
Shrubs		
Arctostaphylos patula	X	X
Ceanothus velutinus	X	X
Chrysolepis sempervirens	X	—
Ericameria bloomeri	X	X
Prunus emarginata	X	X
Ribes spp.	X	X
Forbs		
Gayophytum spp.	X	X
Hackelia spp.	X	X
Madia spp.	—	X
Monardella spp.	X	X
Viola spp.	X	X
Unknown	—	X
Graminoids		
Achnatherum spp.	X	X
Carex spp.	X	X
Elymus elymoides	—	X

Table 2—*Average density, cover, and height with standard errors (SE) of snowbrush, greenleaf manzanita, goldenbush, and graminoids in the control, 1986-1995*

Species	Year	Density	SE	Cover	SE	Height	SE
		plants/acre		*ft²/acre*		*ft*	
Snowbrush	1986	6,350	3,293	950	310	0.4	0.1
	1989	5,550	2,998	7,900	1,034	1.5	0.1
	1991	4,050	2,034	13,750	1,090	2.2	0.1
	1995	3,500	1,559	16,350	2,001	2.9	0.3
Greenleaf manzanita	1986	4,350	1,075	150	150	0.1	0
	1989	14,050	5,777	500	191	0.5	0.1
	1991	14,400	7,668	1,450	918	0.8	0.1
	1995	10,900	5,827	4,200	2,354	1.6	0.1
Goldenbush	1986	450	263	250	189	0.7	0.1
	1989	15,950	11,459	1,300	714	0.9	0.1
	1991	22,900	13,128	2,700	1,808	0.9	0.2
	1995	17,400	7,202	2,950	1,335	1.1	0.1
Graminoids	1986	1,700	1,063	100	58	0.7	0.1
	1989	33,250	10,965	1,400	469	1.5	0.5
	1991	38,000	9,104	1,800	622	1.6	0.3
	1995	65,050	12,528	1,800	455	2.1	0.2

Although not significant, the higher density and foliar cover of snowbrush plants in the T-first-3 treatment, relative to the T-first-6 and T-second-3 treatments indicated recruitment and subsequent growth of new snowbrush seedlings after 3 years.

Greenleaf Manzanita

Greenleaf manzanita, almost all from buried seed, became abundant early in the study in the control (4,350 plants per acre), peaked in 1991 (14,400 plants), and then declined (10,900 plants per acre) by the end of the study (*table 2*). Foliar cover and height increased steadily throughout the study, and in 1995, averaged 4,200 ft² per acre and 1.6 feet, respectively. Manzanita was noted as lightly browsed in 1988, and heavily browsed in 1990.

Among treatments in 1995, manzanita density and foliar cover did not differ significantly among treatments, but average height was significantly shorter in the T-first-6 and T-second-3 treatments (0.7 ft) than in the T-first-3 treatment (1.3 ft) and the control (1.6 ft) (*table 3*). Average density ranged from 5,350 plants per acre in the T-first-6 treatment to 10,900 plants per acre in the control, and foliar cover ranged from 200 ft² per acre in the T-first-6 treatment to 4,200 ft² per acre in the control.

Goldenbush

Once called rabbitbrush, goldenbush, like other species in the genera *Chrysothamnus*, *Haplopappus*, and *Ericameria*, is noted for its abundance and ability to grow well on poor sites (Sampson and Jespersen 1963). It is rated as a severe competitor to conifer seedlings in young plantations (Click and others 1989) because seed crops are frequent and heavy, and it is one of the first shrubs to invade a disturbed area (Mozingo 1987). In our study, goldenbush seedlings were noted as being the first to reinvade the newly grubbed plots in the T-second-3 treatment. No browsing was noticed during the study.

In the control, average goldenbush density was relatively low in 1986 (450 plants per acre), peaked in 1991 (22,900 plants per acre), and then decreased by the end of the study in 1995 (17,400 plants per acre) (*table 2*). Average foliar cover increased steadily from 250 to 2,950 ft² per acre and height from 0.7 to 1.1 feet during the study.

Table 3—*Average density, foliar cover, and height of snowbrush, greenleaf manzanita, goldenbush, and graminoids among treatments, northern California, 1995*

Species	Treatment	Density	Cover	Height
		plants/acre	*ft²/acre*	*ft*
Snowbrush	Treated first 6 year	900 a[1]	0 a	0.5 a
	Treated first 3 years	950 a	2,600 a	1.0 a
	Treated second 3 years	550 a	850 a	1.4 a
	Control	3,500 b	16,350 b	2.9 b
	Standard error[2]	7.41	1,580	0.27
	F ratio[2]	3.76	23.590	15.157
	P value[2]	0.041	0.0001	0.0001
Greenleaf manzanita	Treated first 6 years	5,350 a	200 a	0.7 a
	Treated first 3 years	5,850 a	2,100 a	1.3 b
	Treated second 3 years	7,650 a	550 a	0.7 a
	Control	10,900 a	4,200 a	1.6 b
	Standard error	16.93	1,204	0.12
	F ratio	1.02	2.292	13.799
	P value	0.419	0.130	0.0001
Goldenbush	Treated first 6 years	14,000 a	1,600 a	0.9 a
	Treated first 3 years	3,400 a	550 a	0.7 a
	Treated second 3 years	12,400 a	3,200 a	1.3 a
	Control	17,400 a	2,950 a	1.1 a
	Standard error	23.02	1,015	0.15
	F ratio	1.89	1.481	3.367
	P value	0.186	0.269	0.055
Graminoids	Treated first 6 years	67,200 a	4,550 ab	2.6 a
	Treated first 3 years	91,600 a	6,300 a	2.0 a
	Treated second 3 years	67,900 a	3,600 ab	2.0 a
	Control	65,050 a	1,800 b	2.1 a
	Standard error	23.19	941	0.15
	F ratio	1.802	3.977	2.688
	P value	0.419	0.035	0.093

[1]For each species, treatment means in each column followed by the same letter do not differ statistically at the 0.05 level.

[2]Standard error, F, and P for density of all species and categories are transformed (sqrt) values.

Among treatments in 1995, time since disturbance did not appear to be a factor affecting average density, foliar cover, or height. Density ranged from 3,400 to 17,400 plants per acre, foliar cover from 550 to 3,200 ft^2 per acre, and height from 0.7 to 1.3 feet (*table 3*). No differences among treatment means were statistically significant.

Graminoids

Almost all plants in this category were from the genera *Elymus (*formerly *Sitanion;* Hickman 1993), *Achnatherum* (formerly *Stipa*; Hickman 1993), and *Carex*. As early as fall 1986, a few grass plants were noted as invading recently sprayed plots. New grass seedlings also were noted as becoming "really dense" in T-first-6 and T-first-3 plots in 1988 and 1989. Some clipping of grass was noted in fall 1990.

Graminoids in the control numbered 1,700 per acre in 1986 with only minor amounts of foliar cover and height (*table 2*). However, by 1991, density had increased to more than 38,000 plants per acre with more than 1,800 ft^2 of foliar cover per acre and an average height of 1.6 feet. These values remained relatively similar through 1995 with the exception of graminoid density, which increased greatly to more than 65,000 plants per acre.

Among treatments in fall 1995, average density of graminoids ranged from slightly more than 65,000 to 91,600 plants per acre, and average height from 2.0 to 2.6 feet (*table 3*), but neither was statistically significant at the 5 percent level. Foliar cover, however, was statistically lower in the control (1800 ft^2 per acre) than in the T-first-3 treatment (6,300 ft^2 per acre).

Table 4—*Average diameter, height, and foliar cover of California white fir seedlings, by treatment, northern California, 1986-1995*

Treatment	1986	1988	1989	1991	1995
	Height (*ft*)				
Treated first 6 years	0.61 a[1]	1.09 a	1.33 a	2.73 a	4.76 a
Treated first 3 years	0.58 a	1.11 a	1.39 a	2.54 a	3.41 a
Treated second 3 years	0.59 a	0.96 a	1.08 a	1.78 b	2.37 ab
Control	0.59 a	1.05 a	1.18 a	1.65 b	2.35 b
Standard error	0.03	0.07	0.08	0.12	0.31
F ratio	0.22	0.96	3.18	19.96	13.98
P value	0.881	0.442	0.064	0.000	0.000
	Diameter (*inches*)				
Treated first 6 years	—	0.22 a	0.26 a	0.68 a	1.57 a
Treated first 3 years	—	0.21 a	0.26 a	0.63 a	1.20 b
Treated second 3 years	—	0.16 a	0.26 a	0.42 b	0.80 c
Control	—	0.18 a	0.19 a	0.34 b	0.67 c
Standard error	—	0.02	0.02	0.03	0.08
F ratio	—	1.71	2.54	24.65	24.41
P value	—	0.218	0.105	0.000	0.000
	Foliar cover (*ft^2/acre*)				
Treated first 6 years	—	600.00 a	750.00 ab	2,400.00 a	5,950.00 a
Treated first 3 years	—	350.00 ab	900.00 a	2,150.00 a	2,800.00 b
Treated second 3 years	—	0.00 b	350.00 ab	1,050.00 b	1,500.00 bc
Control	—	150.00 b	200.00 b	700.00 b	800.00 c
Standard error	—	98	117	232	344
F ratio	—	7.04	7.88	12.73	44.04
P value	—	0.005	0.004	0.000	0.000

[1]For each year, treatment means followed by the same letter do not differ significantly at the 0.05 level.

California White Fir

Damage to California white fir seedlings was caused primarily by deer browsing with some frost damage to tender new shoots, and some winter wind dessication of hardened-off shoots. Only when the terminal shoot was killed was "damage" recorded; death of lateral shoots, for example, was not tallied. Of the 58 damaged seedlings, 50 were browsed by deer in 1989 and 8 more were damaged by frost and wind in 1991. Mortality was relatively low. Of the 480 seedlings in the study, 67 died: 38 in 1986, 13 in 1989, none in 1991, and 16 in 1995. Among treatments, 3 seedlings died in the T-first-6 treatment, 7 in the T-first-3 treatment, 17 in the T-second-3 treatment, and 40 in the control. The cause of mortality was competition, ultimately drought, aggravated by deer browsing. Tukey tests showed that mortality was significantly lower in the T-first-6 and T-first-3 treatments than in the control. At the end of the study, survival over all treatments was 86 percent.

Statistically significant differences among treatments for California white fir first became evident in fall 1988 when seedlings in the T-first-6 plots had significantly more foliar cover than those in the control and in the T-second-3 treatment (*table 4*). The following year (1989), seedlings in the T-first-3 treatment had significantly more cover than those in the control. Average stem height and diameter did not differ significantly among treatments until fall 1991.

Average height of California white fir seedlings increased steadily in all treatments and, by the end of the study in 1995, ranged from 4.8 feet in the T-first-6 treatment to 2.4 feet in the control (*fig. 1*; *table 4*). Seedlings in the T-first-6 and T-first-3 treatments (3.4 feet) were significantly taller than counterparts in the control. Seedlings in the T-second-3 treatment (2.4 feet) did not significantly differ from any

Figure 1—Growth of California white fir seedlings and development of the plant community, by treatment (A) T-first-6, (B) T-first-3, (C) T-second-3, and (D) control, September 1995.

A

B

C

D

other treatment in 1995. Average stem diameter, measured at 12 inches above mean groundline, also steadily increased, and by the end of the study ranged from 1.6 inches in the T-first-6 plots to 0.7 inch in the control (*table 4*). Like stem height, diameter values for white fir in the T-first-6 and T-first-3 plots (1.2 inches) were significantly larger than those in the control. Seedlings in these two treatments also differed significantly from those in the T-second-3 treatment (0.8 inch), which did not differ from the control. Foliar cover of white fir seedlings in 1995 was characterized by seedlings in the T-first-6 and T-first-3 treatments (5,950 and 2,800 ft^2 per acre, respectively) being significantly larger than seedlings in the control (800 ft^2 per acre) (*table 4*). Of note was that white fir seedlings in the T-first-6 treatment had a significantly larger average stem diameter than seedlings in the T-first-3 treatment (1.57 versus 1.20 inches) and had significantly more foliar cover (5,980 versus 2,800 ft^2 per acre).

Graphs of average height, diameter, and foliar cover over time (*figs. 2, 3,* and *4*) show the effect of treatment on the development of California white fir seedlings.

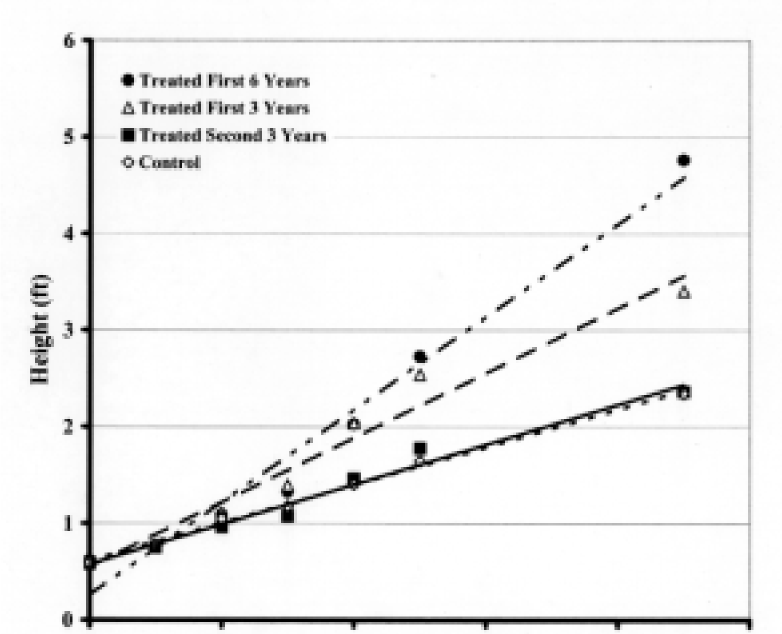

Figure 2—Trend of average California white fir stem height to various treatments, northern California, 1986-1995.

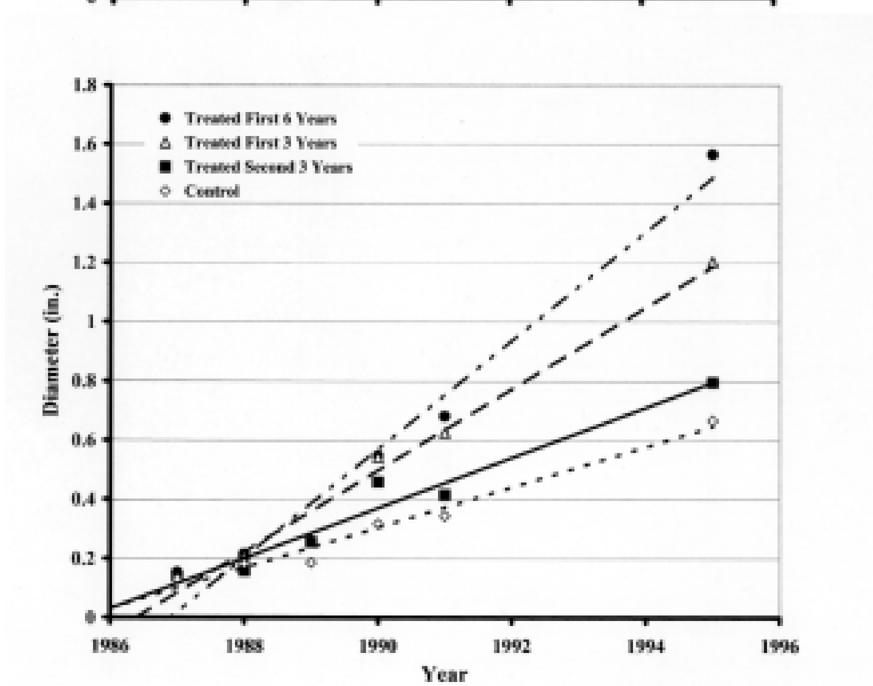

Figure 3—Trend of average California white fir stem diameter to various treatments, northern California, 1986-1995.

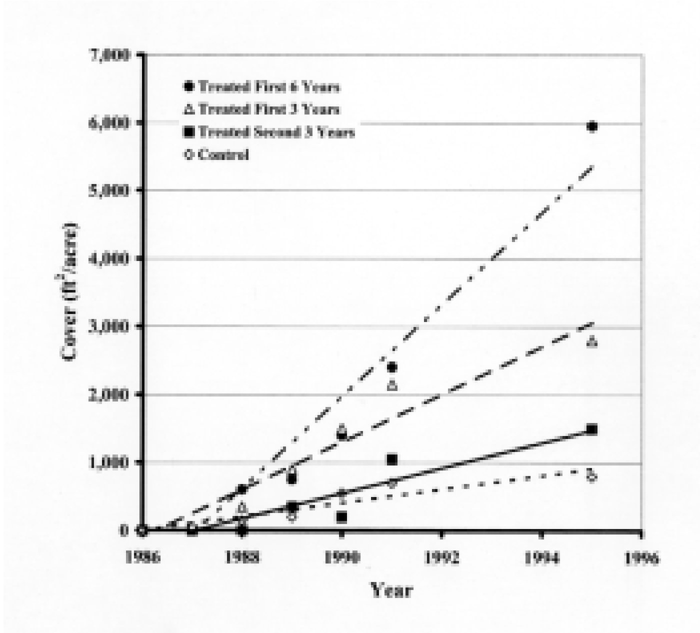

Figure 4—Trend of average foliar cover of California white fir seedlings to various treatments, northern California, 1986-1995.

Discussion and Conclusions

A major need in forestry today is to develop knowledge on plant species and communities that develop after site preparation and after additional disturbance such as that incurred in release. Another need is to develop treatments and treatment schedules that provide consistent and reliable conifer seedling survival and growth rates. Key components of treatment schedules are the efficacy of the treatment, time relative to planting date when the treatment is applied, and the intensity (duration) of the treatment. At some point, delayed release might not be more effective than never releasing, or releasing each year for several years might not be more effective than releasing for 1 or 2 years.

Timing of treatment, and to a lesser extent, duration of treatment, proved to be important. Although treatment did not result in significantly lower density values for two of the three shrub species or the graminoids, it did cause significantly lower amounts of density and foliar cover of snowbrush and significantly taller plants than for counterparts in the control. Interestingly, early treatment also led to significantly lower values of graminoid foliar cover in the control relative to that in the T-first-3 treatment. Too much foliar cover by the shrubs is the likely reason. McDonald and Abbott (1997) noted a similar relationship of grass to shrubs on a site of similar quality at a lower elevation near Mt. Shasta. Treating each year for 6 years as in the T-first-6 treatment resulted in about one-third the amount of foliar cover of all shrubs combined as treating for the first 3 years. Treating each year for 6 years also reduced the foliar cover of combined shrubs to about one-thirteenth of that in the untreated control.

The relationship of early treatment to survival and growth is even more strongly expressed for white fir seedlings. At the end of the study in 1995, seedling mortality was significantly less in the T-first-6 and T-first-3 treatments than in the control, and average height, diameter, and foliar cover were significantly larger in the T-first-6 and T-first-3 treatments than in the control. Delaying release as in the T-second-3 treatment yielded average white fir seedling height, diameter, and foliar cover values that did not differ significantly from those of seedlings in the control.

Early release also can reduce costs. Delaying release usually means larger competing plants with better developed and deeper root systems. Although costs were not recorded in this study, some general observations were noted: spraying took less time than grubbing; grubbing young small plants as in the T-first-3 treatment was much easier than initially grubbing the larger 3-year-old plants in the T-second-3 treatment; and additional treatment applications after the initial work as in the T-first-6 treatment were much more expensive than in the T-first-3 treatment that had half the visits.

The statistically larger values of white fir diameter and foliar cover in the T-first-6 treatment relative to those in the T-first-3 treatment, and the increasing divergence of the trend lines for the two treatments (*figs. 2-4)*, suggest that treating for the first 6 years may be a good investment in spite of the additional cost. If nothing else, it provides the forest manager with another cost-benefit option on which to make future decisions.

Damage and death of white fir seedlings during this 10-year study are best described as low. Several authors (Laacke 1990, Minore 1979, Schubert 1956) have noted that this species is susceptible to damage from spring frosts and deer. Although they were the primary causes of damage in this study, their effect was minor. The overall survival rates of 92 percent after one growing season and 86 percent after ten seasons in this study are much higher than those reported in the literature. For example, for all National Forests in California after the 1966 growing season, average survival of California white fir seedlings was 45 percent after one growing season and 35 percent after three seasons (Landram 1997). Even survival in the control in this study (67 percent after 10 years) was relatively high.

These values, plus similarly high survival rates for California red fir (98 percent after one growing season; 89 percent after ten seasons), in a "sister" study nearby (McDonald and Fiddler 1997a) can be attributed to early removal of competing shrubs, especially of the aggressive snowbrush and greenleaf manzanita and the obviously good job of planting with vigorous seedlings.

During the 10-year length of this study, the plant community was composed of 16 species, 15 at the end of the study. Relative to other young plantations in our National Administrative Study, this number places it last in terms of species richness. The range was 17 to 41 species (McDonald and Fiddler), which expanded to 46 species in a later study (McDonald and Fiddler 1997b). Colonization by a low number of well adapted species is not unusual on a harsh site such as that in this study where the winters are severe, the summers are hot and dry, and the growing season is short. The plant community is one where the shrubs and graminoids dominate. At the end of the study, at least 87,000 plants per acre were present in all treatments, with 69 to 90 percent being graminoids. Foliar cover was a good indicator of differences in plant development, with snowbrush and greenleaf manzanita having a strong and positive response to treatment, and goldenbush and the graminoids having a mixed and weak response. For graminoids, recently disturbed bare ground led to higher amounts of foliar cover than that which was occupied by other vegetation, but height was independent of treatment or the ensuing vegetation brought about by it.

The density and developmental trends in the control suggest the future composition and growth of the plant community in the absence of release. Plainly, snowbrush will thrive. With 16,350 ft^2 per acre of foliar cover and 2.9 feet of height after 10 years, it clearly is, and will continue to be, the dominant vegetation in the plantation. Greenleaf manzanita, with its relatively high density and rapidly developing foliar cover and height, is likely to be a major part of the future plant community as well. The future role of goldenbush and the graminoids in the control is less certain. Although average density is high, their foliar cover and height is barely increasing or increasing at a decreasing rate. Both will probably be present in small openings among the other species.

Among the treatments in 1995, the interplay between the competing vegetation and the white fir seedlings suggests the species composition of the future plant community. In the T-first-6 and the T-first-3 treatments, average foliar cover and height of the seedlings exceeds that of the three shrub species and suggests their continued dominance. Average height, diameter, and foliar cover of white fir in these two treatments accelerated, compared to the T-second-3 treatment and control (*figs. 2-4*). The future plant community in these treatments will be that of white fir above and some shrubs and graminoids below. With time and increasing shade, plants in both categories will become less vigorous. In the

T-second-3 treatment, the density, foliar cover, and height of some of the vegetation could be a threat to the future development of the white fir seedlings. In the control, average foliar cover of the shrubs and graminoids are much higher than that of the white fir seedlings, and height of snowbrush is higher. These values, plus the high density of the competing vegetation, indicate strong competition to the white fir seedlings. In the future, the plant community here will likely be a mix of shrubs and slow-growing white firs with a scattering of forbs and grasses among them.

Early removal of competing vegetation by site preparation and release denies undesirable plants the chance to utilize the high levels of site resources typically present after disturbance. Timing of release is critical. Early release in this study allowed the white fir seedlings to capture adequate site resources, become established, and grow well. Restoring the arboreal component of the plant community, which historically has been part of it, should create a forest stand and a more desirable and sustainable vegetative assemblage than that present before the study began.

References

Biging, Greg S; Wensel, Lee C. 1984. **Site index equations for young-growth mixed conifers of northern California.** Res. Note 8. Berkeley: Department of Forestry and Resource Management, University of California; 13 p.

Click, Chris; Fiske, John N.; Sherlock, Joseph; Wescom, Robert. 1989. **Alternatives to herbicides--update based on the five-year herbicide use moratorium in the USDA Forest Service Pacific Southwest Region**. In: Proceedings, 10th annual forest vegetation management conference; 1988 November 1-3; Eureka, CA. Redding, CA: Forest Vegetation Management Conference; 49-90.

Daubenmire, R.F. 1968. **Plant communities: a textbook on plant synecology**. New York: Harper and Row; 300 p.

Fiddler, Gary O.; McDonald, Philip M. 1984. **Alternatives to herbicides in vegetation management: a study**. In: Proceedings, 5th annual forest vegetation management conference; 1983 November 2-3; Sacramento, CA. Redding, CA: Forest Vegetation Management Conference; 115-126.

Fiddler, Gary O.; McDonald, Philip M. 1987. **Alternative treatments for releasing conifer seedlings: a study update**. In: Proceedings, 8th annual forest vegetation management conference; 1986 November 4-6; Sacramento, CA. Redding, CA: Forest Vegetation Management Conference; 64-69.

Fitzgerald, Dick; Loomis, Robert; Booser, Jo; MacMeeken, Sue; Fiske, John. 1991. **Reforestation activity review, Region 5**. Washington, DC: Forest Service, U.S. Department of Agriculture; 12 p.

Gordon, Donald T. 1970. **Natural regeneration of white and red fir, influence of several factors**. Res. Paper PSW-58. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 32 p.

Gordon, Donald T. 1980. **White fir**. In: Eyre, F. H., editor. Forest cover types of the United States and Canada. Washington, DC: Society of American Foresters; 92-93.

Gordon, Donald T.; Bowen, Eugene E. 1978. **Herbs and brush on California red fir regeneration sites: a species and frequency sampling**. Res. Note PSW-329. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 10 p.

Hickman, James C., editor. 1993. **The Jepson manual, higher plants of California**. Berkeley: University of California Press; 1,400 p.

Hunt, L.O. 1963. **Evaluation of various mulching materials used to improve plantation survival**. Tree Planters Notes 57: 19-22.

Jackson, Louise E. 1985. **Ecological origins of California's Mediterranean grasses**. Journal of Biogeography 12: 349-361.

Laacke, Robert J. 1990. ***Abies concolor* (Gord. & Glend.) Lindl. ex Hildebr. White fir**. In: Burns, Russell M.; Honkala, Barbara H., technical coordinators. Silvics of North America, Volume 1. Conifers. Washington, DC: Forest Service, U.S. Department of Agriculture; 36-46.

Laacke, Robert J.; Fiske, John N. 1983. **Red fir and white fir**. In: Burns, Russell M., technical compiler. Silvicultural systems for the major forest types of the United States. Washington, DC: Forest Service, U.S. Department of Agriculture; 41-43.

Landram, F. Michael. 1997. **Plantation survival report**. Pacific Southwest Region, Forest Service, U.S. Department of Agriculture; 1 p.

Logan, Robert S. 1983. **Agro-forestry: growing trees, forage, and livestock together**. Extension Circular 1114. Corvallis: Oregon State University; 4 p.

McDonald, Philip M. 1982. **Adaptations of woody shrubs**. In: Hobbs, S.D.; Helgerson, O.T., editors. Proceedings of a workshop on reforestation of skeletal soils; 1981 November 17-19; Medford, OR. Corvallis, OR: Forest Research Laboratory, Oregon State University; 21-29.

McDonald, Philip M. 1999. **Diversity, density, and development of early vegetation in a small clear-cut environment.** Res. Paper PSW-RP-239. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 22 p.

McDonald, Philip M.; Abbott, Celeste S. 1997. **Vegetation trends in a 31-year-old ponderosa pine plantation: effect of different shrub densities**. Res. Paper PSW-RP-231. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 35 p.

McDonald, Philip M.; Fiddler, Gary O. 1989. **Competing vegetation in ponderosa pine plantations: ecology and control**. Gen. Tech. Rep. PSW-113. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 26 p.

McDonald, Philip M.; Fiddler, Gary O. 1993. **Feasibility of alternatives to herbicides in young conifer plantations in California**. Canadian Journal of Forest Research 23: 2015-2022.

McDonald, Philip M.; Fiddler, Gary O. 1997a. **Treatment duration and time since disturbance affect vegetation development in a young California red fir plantation**. Res. Paper PSW-RP-233. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 14 p.

McDonald, Philip M.; Fiddler, Gary O. 1997b. **Vegetation trends in a young ponderosa pine plantation treated by manual release and mulching**. Res. Paper PSW-RP-234. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 15 p.

McDonald, Philip M.; Fiddler, Gary O. 2001. **Timing and duration of release treatments affect vegetation development in a young ponderosa pine plantation**. Res. Paper PSW-RP-245. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 14 p.

McDonald, Philip M.; Fiddler, Gary O.; Meyer, Peter W. 1996. **Vegetation trends in a young conifer plantation after grazing, grubbing, and chemical release.** Res. Paper PSW-RP-228. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 17 p.

Minore, Don. 1979. **Comparative autecological characteristics of northwestern tree species—a literature review.** Gen. Tech. Rep. PNW-87. Portland, OR. Pacific Northwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 72 p.

Mooney. Harold A.; Dunn, E. Lloyd. 1970. **Convergent evolution of Mediterranean-climate evergreen schlerophyll shrubs**. Evolution 24: 293-303.

Mozingo, Hugh N. 1987. **Shrubs of the Great Basin**, **A natural history**. Reno, Las Vegas: University of Nevada Press; 287 p.

Rundel, Philip W.; Parsons, David J.; Gordon, Donald T. 1977. **Montane and subalpine vegetation of the Sierra Nevada and Cascade Ranges**. In: Barbour, Michael G.; Major, Jack, editors. Terrestrial vegetation of California. New York: John Wiley and Sons; 559-599.

Sampson, Arthur W.; Jespersen, Beryl S. 1963. **California range brushlands and browse plants**. Manual 33. Berkeley: University of California Agricultural Experiment Station Extension Service; 140-142.

SAS Institute, Inc. 1988. **SAS procedures guide**, release 6.03 edition. Cary, NC: SAS Institute, Inc.

Schubert, Gilbert H. 1956. **Early survival and growth of sugar pine and white fir in clear-cut openings**. Res. Note 117. Berkeley, CA: California Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 6 p.

Steel, Robert C.D.; Torrie, James H. 1980. **Principles and procedures of statistics.** 2nd ed. New York: McGraw-Hill Book Company; 218-220.

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Timing and Duration of Release Treatments Affect Vegetation Development in a Young California White Fir Plantation