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Treatment Duration and Time Since Disturbance Affect Vegetation Development in a Young Ponderosa Pine Plantation

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The effect of early and delayed release treatments (designated as "Treat first 3 years" and "Treat second 3 years," respectively) on diameter, height, and foliar cover of ponderosa pine seedlings, and density, foliar cover, and height of competing vegetation was evaluated in a young northern California plantation. Manual grubbing created vegetation recovery times (the period of time from the last release treatment until the end of the study) that lasted 4 to 10 years. Duration and timing of the grubbing operations constituted the treatments. Development of species other than the planted pines was evaluated directly for density, cover, and height, and indirectly for effect on pine survival and growth. By 1995 greenleaf manzanita had higher values for density, cover, and height in the treatments allowing the longest recovery times. Survival of the ponderosa pines over all treatments after 1 growing season was 99 percent and after 10 seasons was 96 percent. Both release treatments
(*continued on page 2*)

Introduction

The establishment of conifer plantations in California is often an arduous and continuing task. Almost all new plantations will be invaded by competing plant species in the form of hardwoods, woody shrubs, grasses, and forbs.[1] The onset of competition is often rapid and its intensity formidable.[2] The composition of the plant communities affects the magnitude of competition in young conifer plantations and has been shown to influence conifer seedling survival and growth in a negative manner.[3,4,5] In order to ensure acceptable growth, and indeed the survival of the conifer seedlings in these plantations, this competition needs to be controlled.

Release is the common control method used in plantations in California. The timing of the release treatment is an important component in the release program. Numerous research findings indicate that in order for planted conifers to develop at or near the potential of the site, the conifer seedlings must be released from competing vegetation early in the life of the plantation. "Early" usually is defined as the first or second year after outplanting.[6,7,8]

Despite the need for early release, this activity often is postponed until the third or fourth growing season. Lack of adequate budgets and shrinking resources are the most common causes of these postponements. Is this delayed release efficient and cost effective? Is releasing several years in a row later in the life of a plantation as effective as releasing for the first 1 or 2 years after plantation establishment? Release after 4 years is generally not cost-effective because the competing vegetation has become large and well established with well developed root systems.[2]

To increase knowledge on the ecology of several widespread plant species and on a plant community that is commonplace in California and Oregon, information was collected on the growth dynamics and competitive relationships of vegetation reoccupying a timber-harvested site in northern California. Planted ponderosa pine (*Pinus ponderosa* Dougl. ex Laws. var. *ponderosa*) seedlings were part of the plant community. As part of the USDA Forest Service's National Administrative Study on alternative release methods,[9] data were gathered from 1985-1995 on vegetation developing naturally in an untreated control and on vegetation manipulated deliberately by grubbing to create different time spans. The time spans, or more specifically vegetation recovery times after disturbance by site preparation and release, are the treatments.

This paper reports the results of testing whether there are significant differences in plant community development and recovery between two release treatment schedules 4, 7, and 10 years after manipulation.

Methods

(*continued from page 1*) resulted in greater conifer diameter, height, and foliar cover than in the control at the end of the study. Conifer values between the two release treatments did not differ significantly at the end of the study.

Retrieval Terms: competing vegetation, northern California, ponderosa pine seedlings, release treatments, timing of release

The study site was located on the Goosenest Ranger District of the Klamath National Forest about 21 airline miles northeast of Weed, California. It was harvested as part of the Trapper Springs Timber Sale in 1984. Before harvest, the forest was predominately California white fir (*Abies concolor* var. *lowiana* [Gord.] Lemm.), Shasta red fir (*Abies magnifica* A. Murr.), and ponderosa pine, with occasional Sierra lodgepole pine (*Pinus contorta* var. *murrayana* [Grev. & Balf.] Engelm.) and sugar pine (*Pinus lambertiana* Dougl.).[10,11] Sierra chinquapin (*Castanopsis sempervirens* [Kell.] Dudl.), and to a lesser extent greenleaf manzanita (*Arctostaphylos patula* Greene) and snowbrush (*Ceanothus velutinus* Dougl. ex Hook.), were well developed shrubs in small openings and on rocky outcrops. The forest cover type is white fir.[12] Vegetation in the study area has been placed in the montane and subalpine region of the Sierra Nevada and Cascade Ranges.[13]

Site quality of the study area is medium-poor with height of dominant California white fir averaging about 60 feet in 50 years.[14] Soils are of the Scheld-Iller complex from colluvium, tuff, and igneous parent material. Texture is sandy loam, drainage is excessive, and water holding capacity is low. Stones and occasional aggregations of boulders are abundant throughout the area. The elevation is about 6,200 feet, the slope ranges between 10 and 20 percent, and the aspect is northwest. The study area is uniform with respect to slope, aspect, and soil. Annual precipitation averages 25 inches, with most falling as snow. Thunderstorms often provide critical moisture in the spring and through late summer. Temperatures range from 20°F to 80°F with an average annual temperature of 43°F. The growing season is about 100 days.

The study site was prepared by a brushrake-equipped tractor. The windrows of logging slash and brush were burned in the fall of 1984. Very little soil was displaced, and the windrows could hardly be seen at the start of the study.

Ponderosa pine seedlings from a local seed source were raised at the Stone Nursery in Medford, Oregon, and outplanted as 2-0 seedlings in April 1985. Spacing was 8 by 8 feet. An excellent job of planting was done. Although little precipitation fell on the study area for several months after planting, the pine seedlings looked healthy at the end of the first growing season.

The plant community before the study began consisted mostly of species that originated from sprouts. Chinquapin and, to a lesser extent, snowbrush and greenleaf manzanita, were the most abundant sprouting species. A few manzanita seedlings were the only shrub species from seed that were observed. Grasses were almost absent from the study area, although a few plants were noticed in a plantation nearby. Several species of forbs were present, but none were particularly abundant.

Evidence of deer (*Hemionus* spp.) and black bear (*Ursus americanus*) was noticed. Small rodents and numerous birds were seen.

The study area was located in a large, homogeneous area free of overstory vegetation. The experimental design was completely randomized with a one-way treatment structure. Three treatments, including the control, were each replicated three times. A replicate (plot) consisted of about one-fifth of an acre containing about 40 ponderosa pine seedlings surrounded by 2 to 3 rows of buffer (seedlings receiving similar treatment). The study began in 1985 and ended in 1995.
Treatments and treatment dates were:

T-first-3: Treat first 3 years (1986-1988) and develop naturally the last 7 years.

T-second-3: Delay 3 years, treat the next 3 years (1989-1991), and develop naturally for the last 4 years.

Control: Not treated after site preparation and develop naturally the entire 10 years of the study.

Plots in the T-first-3 and the T-second-3 treatments were grubbed to a 5-foot radius. Vegetation was grubbed below the root crown with hand tools. The work was performed during the summer at a time when growth of the ponderosa pine seedlings had stopped but that of the shrubs was continuing.

In each plot, 25 healthy-looking ponderosa pine seedlings, identified as having good potential of becoming harvestable trees, were selected and tagged before treatment began. Chlorotic and misshapen seedlings that would be removed in the first precommercial thinning were excluded. On each of the sample seedlings, stem diameter (measured at 12 inches above mean ground line) and height were measured. Seedlings were measured annually for the first 7 years of the study with a final measurement being made at the end of the study. The seedlings were periodically checked for injury from animals and insects.

Sampling intensity for evaluating competing vegetation consisted of five randomly selected subplots in each plot. Subplots were centered around ponderosa pine seedlings and encompassed 1 milacre (0.001 acre). Vegetation was 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),[15] and average dominant height (average of the three tallest stems measured from mean ground line to bud). Competing vegetation was evaluated annually for the first 7 years of the study followed by final measurements at the end of the study. More specifically, number of plants in each subplot were counted, foliar cover was visually estimated, and height was measured with a graduated pole. The most abundant vegetation, greenleaf manzanita, was analyzed separately. All other shrubs were combined and analyzed as a group. This group was composed of Sierra chinquapin, snowbrush, and rabbit brush (*Chrysothamnus* spp.). Grass was analyzed as a separate category of vegetation.

To test for treatment effects and significant differences among treatments, one-way analysis of variance of treatment means (fixed effect model)[16] and Tukey tests were applied.[17] Statistical significance in all tests was at $\alpha = 0.05$. Data were gathered from permanent plots measured each year, and for analysis of means from repeated measurements, 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.

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

Results

Ponderosa Pine

Mortality of ponderosa pine during the study period was low. Despite receiving little moisture after planting in spring 1985, first year survival for the entire study was 99 percent. The control and T-first-3 treatment each lost one seedling during this first year. Mortality was attributed to drought. Overall survival of ponderosa pine seedlings on all study plots in all treatments was 96 percent. At the end of the study, percent survival by treatment was:

Treatment	Percent
Control	**95**
T-first-3	**97**
T-second-3	**97**

Despite numerous sightings of deer in the study area, only minor amounts of browsing to the ponderosa pine seedlings were detected. Gophers (*Thomomys* spp.) killed one ponderosa pine seedling in 1988. The pine seedlings suffered winter wind-burn during several years of the study, but overall growth did not seem to be affected. During the winter of 1994, some of the branches of the larger pines were broken or pulled out by snow. No terminals were damaged during this event.

Table 1—*Stem diameter, height, and foliar cover of ponderosa pine seedlings, by treatment, northern California, 1985-1995.*

Treatment	1985	1989	1990	1991	1995
		Diameter (inches)			
Control	-	0.63 a[1]	0.78 a	0.98 a	1.63 a
T-first-3	-	0.91 a	1.34 b	1.59 b	3.00 b
T-second-3	-	0.63 a	1.00 a	1.28 ab	2.80 b
Standard error		0.09	0.10	0.09	0.15
		Height (ft)			
Control	0.46 a	1.92 a	2.44 a	2.93 a	4.77 a
T-first-3	0.45 a	2.46 a	3.43 a	4.32 a	7.88 b
T-second-3	0.42 a	2.01 a	2.77 a	3.56 a	7.35 b
Standard error	0.02	0.23	0.31	0.34	0.45
		Cover (ft^2/acre)			
Control	-	1,400 a	1,800 a	2,067 a	2,733 a
T-first-3	-	2,800 b	4,333 b	5,867 b	14,200 b
T-second-3	-	1,800 ab	2,867 ab	3,600 ab	10,867 b
Standard error	-	306	515	564	1,806

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

Average height of the ponderosa pine seedlings increased steadily in all treatments, and by the end of the study in 1995, it ranged from 7.9 feet in the T-first-3 treatment to 4.8 feet in the control (*table 1*). Statistically significant differences among treatments for ponderosa pine stem height were not present until fall 1995. Seedlings in the T-first-3 and T-second-3 treatments were significantly taller than those in the control.

Stem diameter, measured at 12 inches above mean ground line, increased throughout the study period and by fall 1995 ranged from 3.0 inches in the T-first-3 treatment to 1.6 inches in the control. Significant differences among treatments for ponderosa pine stem diameter were first found in 1990, when mean stem diameter of pines in the T-first-3 treatment was significantly larger than counterparts in the control or T-second-3 treatment (*table 1*). By fall 1991 conifer stem diameter differed only between the T-first-3 treatment and the control. By the end of the study in 1995, ponderosa pine seedlings in the T-first-3 and the T-second-3 treatments had the largest average stem diameters. These two treatments, which did not differ from each other, differed significantly from the control.

The first significant difference in ponderosa pine parameters that could be attributed to treatment effects occurred in foliar cover. By fall 1989, foliar cover of the pine seedlings was significantly larger in the T-first-3 treatment than in the control. This difference continued through 1995. By study end in fall 1995, foliar cover of the ponderosa pine seedlings in the T-first-3 and T-second-3 treatments differed significantly from that of counterparts in the control.

Greenleaf Manzanita

This evergreen, fast-growing shrub was the most abundant species in the control in 1986 and remained abundant throughout the study (*table 2*). Although a few manzanita sprouts were noted, most of these plants originated from viable seeds in the soil that germinated after site preparation. We also noted that manzanita was browsed in 1988 and 1990, probably by deer, and that it suffered from winter windburn in 1990.

Average density of greenleaf manzanita in the control was highest in 1986 (80,533 plants per acre) and declined 25 percent to 60,267 plants per acre in 1995. Foliar cover and height steadily increased from the beginning to the end of the study. Foliar cover increased 82 times from 333 to 27,200 ft^2 per acre and height 13 times from 0.15 to 2.0 feet tall in 1995.

Among treatments, manzanita density in 1995 differed significantly between the T-second-3 treatment and the control (*table 3*). Foliar cover and height were significantly less in both T-first-3 and T-second-3 treatments than in the control. Density, cover, and height values of greenleaf manzanita reflect the ability of this species to rebound from disturbance. The longer the time since disturbance, the higher the values. The control (10 years since disturbance) had 70 times more foliar cover than did the most recent treatment (T-second-3, 4 years since disturbance). Density and height followed the same pattern with the control showing almost eight times more density and almost four times more height than in the T-second-3 treatment. Without treatment, this species tended to decrease in density but increase in foliar cover and height throughout the study. Surviving plants were becoming taller and more robust. This development meant that competition to the planted ponderosa pines increased.

Shrubs

Density of the combined shrubs was much less than that of the most numerous shrub, greenleaf manzanita (*table 2*). This group of shrubs suffered from winter wind-burn in 1988, 1989, and 1990. Grazing damage was noted on snowbrush in 1990.

Density increased from 1986 (3,733 plants per acre) through 1990 (7,066 plants per acre) and then decreased to 4,067 plants per acre by the end of the study. This represented an increase of 9 percent during the study. Foliar cover followed a similar pattern, peaking in 1991 at 2,333 ft^2 per acre and declining to 1,733 ft^2 per acre by 1995, which was an increase of 189 percent. Height increased throughout the study from 0.20 feet in 1986 to 1.2 feet in 1995, which was a gain of 565 percent.

Among treatments in fall of 1995, average density of combined shrubs ranged from 300 to 4,067 plants per acre, foliar cover from 200 to 1,733 ft^2 per acre, and height from 1.0 to 1.2 feet (*table 3*). Statistical differences were not found among treatments for density, cover, or height. Similar to greenleaf manzanita, this group of shrubs tended to decrease in density and increase in

Table 2—*Density, cover, and height, with standard errors (SE), of greenleaf manzanita, shrubs, and grass in the control, northern California, 1986-1995.*

Year	Density	SE	Cover	SE	Height	SE
	plants/acre		ft^2/acre		ft	
Greenleaf manzanita						
1986	80,533	21,259	333	196	0.15	0.00
1989	67,467	12,643	9,267	1,714	0.71	0.04
1990	71,800	12,845	12,600	2,075	0.97	0.07
1991	53,800	8,234	17,133	2,281	1.20	0.10
1995	60,267	8,977	27,200	1,943	2.00	0.17
Change (pct)	-25		huge		huge	
Shrubs						
1986	3,733	1,416	600	570	0.19	0.05
1989	5,200	1,100	1,533	657	0.56	0.07
1990	7,066	1,603	1,867	615	0.58	0.09
1991	4,733	1,187	2,333	944	0.68	0.19
1995	4,067	1,203	1,733	732	1.24	0.23
Change (pct)	+9		+189		+565	
Grass						
1986	2,000	792	200	121	0.21	0.05
1989	3,200	1,094	400	230	0.50	0.12
1990	5,867	1,675	467	214	0.44	0.13
1991	3,867	1,254	267	101	0.63	0.07
1995	8,333	4,423	67	86	0.48	0.17
Change (pct)	+317		-67		+129	

Table 3—*Density, cover, and height of greenleaf manzanita, shrubs, and grass after 10 growing seasons, by treatment, northern California.*

Treatment	Density plants/acre	Cover ft^2/acre	Height ft
Greenleaf manzanita			
Control	60,267 a[1]	27,200 a	2.00 a
T-first three	25,867 ab	2,400 b	1.10 b
T-second three	7,933 b	400 b	0.54 b
Standard error	8,977	1,943	0.17
Shrubs			
Control	4,067 a	1,733 a	1.24 a
T-first three	1,200 a	200 a	0.56 a
T-second three	300 a	500 a	0.98 a
Standard error	1,203	732	0.23
Grass			
Control	8,333 a	67 a	0.48 a
T-first three	5,533 a	67 a	0.43 a
T-second three	6,533 a	200 a	0.43 a
Standard error	4,423	86	0.17

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

height throughout the study, but unlike manzanita, foliar cover was decreasing at the end of the study. Competition from the taller manzanita and the ponderosa pine probably was negatively impacting this group.

Grass

Almost all plants in this category were from the genera *Bromus* or *Achnatherum* (formerly *Stipa*).[11] Almost absent from the study area at the start of the study, density increased to 2,000 plants per acre by fall 1986 (*table 2*). And during the study, density increased from 2,000 to 8,333 plants per acre for a gain of over 300 percent. Cover increased from 200 ft^2 per acre in 1986 to 467 ft^2 per acre in 1990. It decreased from this amount to 67 ft^2 per acre by the end of the study, which was an overall decrease of 67 percent. Height increased from 0.2 feet in 1986 to 0.5 feet in 1995 for gain of 129 percent. Damage from grazing was noted in 1990.

Among treatments in fall of 1995, average density of grass ranged from 5,533 plants per acre in the T-first-3 treatment to 8,333 plants per acre in the control (*table 3*). Cover ranged from 67 to 200 ft^2 per acre, and height was basically the same in all treatments with a value slightly less than 0.5 feet. No statistical differences were found among treatments for density, cover, or height.

Discussion

This study at Trapper Springs differs from most studies in the Forest Service's National Administrative Study on alternative release methods in that it is one of five studies designed to document the recovery of vegetation after a series of manipulations that were applied at different times and continued for various durations. The hypothesis tested was that the amount of vegetation and the time that it was present, relative to release, would affect various species in the community, and in turn affect the conifer seedlings. The actual release methods—grubbing in the case of Trapper Springs—accomplished the treatments. The different timings and durations were the treatments.

Plantations in California need site preparation and release in order for the planted conifer seedlings to survive in adequate numbers and grow at acceptable rates to meet management objectives. Timing of this release is critical. Conifers

released early (within the first 3 years after planting) are able to capture enough site resources to become established and grow at rates near the potential of the site. In this study, the T-first-3 and T-second-3 treatments were designed specifically to test early versus delayed release for ponderosa pine.

Results from numerous studies have shown that early release is more cost effective (including degree of vegetation response and cost of release treatment) than delayed release.[18,19] This study supports that finding. In 1990, 5 years after release, ponderosa pine seedlings from the T-first-3 treatment had significantly larger diameters than those seedlings in the T-second-3 treatment. In 1991 seedlings in the T-first-3 treatment, although still larger than those in the T-second-3 treatment, did not differ from them at the 0.5 percent level—a finding that did not change for the next 4 years. Conifer height and foliar cover in the T-first-3 treatment were greater than their counterparts in the T-second-3 treatment throughout the study, although not statistically. At the end of the study, conifer diameter, height, and foliar cover in the two release treatments differed significantly from those in the control. Thus, release enhanced growth of ponderosa pine seedlings on this poor site, regardless of when initially performed.

The fact that ponderosa pine seedlings can survive with severe competition was demonstrated again at Trapper Springs. Survival of conifers in the control was almost as high (95 versus 97 percent) as it was in the treated plots, despite larger amounts of shrubs and grass. However, their ability to grow at the potential of the site is questionable because of competition.

Cost of treatment is an important factor when evaluating the timing of release. The longer the delay before release, the larger the competing plants and their root systems. Field notes indicated that it took almost twice as long to install the T-second-3 treatment as the T-first-3 treatment. It was much more time consuming to remove the competing vegetation after four seasons of growth (T-second-3) than during the first season of growth (T-first-3). Although early and delayed release did not result in statistically different conifer growth, the cost of early release made it a much more desirable treatment than delaying release for 4 years. Economically, early release (T-first-3) was superior to delayed release (T-second-3) in that it maximized conifer growth while being cheaper to install.

Time since disturbance can be an important factor affecting the amount of natural vegetation that develops in a given area. In this study, grubbing resulted in plant community recovery times of 4 years in the T-second-3 treatment, 7 years in the T-first-3 treatment, and 10 years in the control. Greenleaf manzanita had the highest density, cover, and height in the treatment allowing the longest recovery time (control). Shrubs and grass also had the highest density values in the control.

With the exception of greenleaf manzanita, time since disturbance did not greatly affect the species composition of the plant community during the study. The same species that were present initially are present at the end of the study, and their overall density and development were similar. A few forbs, their numbers too few to be statistically analyzed, were also present. Shrub densities are declining with surviving plants becoming more robust. Greenleaf manzanita will be the dominant shrub in the plant community. Although grass numbers were at an all time high at the end of the study, grass cover has declined greatly since 1986. Thus, the grasses will occupy a place in the community, but will be relegated to a minor role.

The dominant species in the community of the future will be the planted ponderosa pines. The early release treatments have allowed these conifers to more fully occupy the site and to establish a young forest at an earlier age.

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