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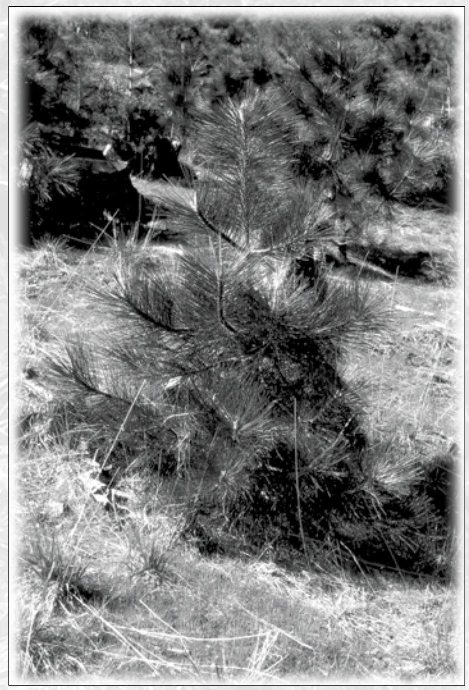
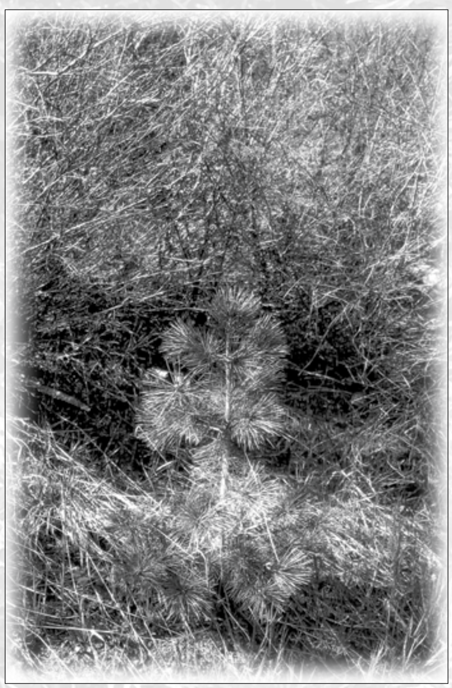
Development of Vegetation in a Young Ponderosa Pine Plantation: Effect of Treatment Duration and Time Since Disturbance

Philip M. McDonald and Gary O. Fiddler





Authors

Philip M. McDonald is a research forester (retired), Pacific Southwest Research Station, Western Forest Management Research Unit, 3644 Avtech Parkway, Redding, CA 96002; e-mail: pmcdonald@fs.fed.us. **Gary O. Fiddler** is a silviculturist, Ecosystem Conservation Staff; San Francisco and stationed at the above address in Redding, CA; e-mail: gfiddler@ fs.fed.us.

Abstract

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The density and development of deerbrush (*Ceanothus integerrimus* Hook. & Arn.), other shrubs, forbs, graminoids, and ponderosa pine (*Pinus ponderosa* Dougl. ex Laws. var. *ponderosa*) seedlings were evaluated in a young plantation in northern California from 1988 through 1997. Treatment regimes consisted of manual release (grubbing) over 3 to 6 years and resulted in vegetation recovery times of 4 to 10 years. Revegetation was remarkably diverse, rapid, and vigorous. At the end of the study, the dominant shrub, deerbrush, had significantly lower average density and foliar cover relative to the control when treated either the first 3 years or the second 3 years, but average height was similar regardless of treatment. Average density of the 11 other shrubs was statistically higher in the control relative to other treatments, but cover and height did not differ. Density, foliar cover, and height of the forbs and graminoids did not differ among treatments at the end of the study. In the control, deerbrush plants numbered 6,100 per acre; other shrubs, 2,550 per acre; forbs, 27,300 per acre; and graminoids, 5,800 plants per acre in 1997. Foliar cover of deerbrush at 22,700 ft^2 per acre was more than five times that of all other naturally established species combined and slightly exceeded that of pine seedlings in all treatments. Average height of pine seedlings ranged from 7.7 ft with intensive release to 5.6 ft with no release. In general, release statistically improved pine growth regardless of timing or duration, but delayed release was more costly.

Keywords: Competing vegetation, northern California, plant succession, ponderosa pine seedlings, timing of release, vegetation management.

Summary

This paper presents the density and development of shrub and herbaceous vegetation that invaded a young conifer plantation in interior northern California on an above-average site at mid-elevation (4,500 ft). It also quantifies the survival and growth of planted ponderosa pine (*Pinus ponderosa* Dougl. ex Laws. var. *ponderosa*) seedlings relative to this vegetation. A major influence on all the vegetation was the environment of the site, which was characterized by long hot, dry summers and cool, wet winters.

Before this study was begun, the original plant community was one of mature shrubs and a few forbs and graminoids (grass plus sedges) under scattered conifers. After timber harvest and site preparation (broadcast burn in 1987), most of the original species and many new ones appeared from root-crown sprouts (shrubs), from dormant seeds in the soil (shrubs, forbs), and from windblown seeds (forbs, graminoids). In all, 49 species were found in treated plots and control during the 10-year study, which ranked this study second of 21 study areas in number of species (range 17 to 61) in our National Forest Service administrative study on alternative release methods.

This study differs somewhat from typical studies that evaluate alternatives for controlling competing vegetation in young conifer plantations. Most studies examine the direct effect of the release treatments (manual grubbing, mulching, etc.), but in this study, we documented 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 kind and amount of vegetation and when it was present would affect the various species in the community over time and in turn affect the growth of the conifer seedlings. Thus, the effect of the different timings and durations was emphasized. The four release treatments were grubbing every year for the first 6 years, grubbing for the first 3 years, grubbing for the second 3 years (years 4 through 6), and no grubbing at all (control). Of course, the longer the delay before grubbing, the more the vegetation grew and the greater the cost incurred.

Colonization, as quantified in the control, was rapid. After one growing season, the average number of deerbrush plants was 21,500 per acre; other shrubs, 10,050 per acre; forbs, 33,450 per acre; and graminoids, 3,050 plants per acre. By the end of the study, deerbrush dominated, with foliar cover and height increasing more than 17 and 12 times, respectively. Density and foliar cover of other shrubs declined, as did forb density, but forb cover increased slightly. The height of vegetation in both categories increased appreciably. Average density, foliar cover, and

height of graminoids, however, generally increased during the study, with mostly large increases from low values.

Among treatments, average density and foliar cover values were generally higher in the control for deerbrush and other shrub species, but lower for the graminoids. Average height of each species and category of vegetation differed little among treatments at the end of the study.

Time since disturbance, or time for the competing vegetation to recover, often is cited as being important, but in this study, the invasion of so much competing vegetation so soon after site preparation and release masked treatment differences. Thus, statistically significant differences among treatments for ponderosa pine seedlings were not found until 1991 (year 4) for pine diameter and foliar cover. By the end of the study, pine diameter and foliar cover did not differ among treatments but did differ from the control. In this study, all release treatments, no matter when applied or for how long, were beneficial to ponderosa pine seedling growth.

Contents

Introduction

Because of shrinking budgets and a lack of resources, the treatment of competing vegetation in young conifer plantations has often been postponed, sometimes for two or three growing seasons or even longer. After such a delay, the forest vegetation manager often wonders: "Where did all that grass and all those shrubs come from," and "What will they do to the growth of my conifer seedlings?" A larger question often is: "Will it do any good to treat now?"

The early plant community, typical of young plantations, often is quite variable because of differences in plantation history (fire, windthrow), different regeneration strategies of plants in the community (seed and seedling banks, windborne seeds, and rapid growth above- and below-ground (Grime 1979)), and different successional mechanisms (facilitation, tolerance, and inhibition (Connell and Slatyer 1977)). Many species from many categories of vegetation, including conifers, hardwoods, shrubs, forbs, grasses, and ferns, comprise the plant community (McDonald 1999, McDonald and Fiddler 1993). Through natural selection over millions of years, many species are well adapted to dominate in newly disturbed areas. Land recently prepared for planting is nearly ideal because soil moisture levels are high and nutrients generally are plentiful. Competing species almost always develop quickly, often grow faster; and usually deny site resources, especially soil moisture (De Groot 1991), to newly planted conifer seedlings. Death of the young conifers or a slowed growth rate is the usual consequence of not treating the competing vegetation.

Plainly, measures need to be taken to lessen the impact of competing vegetation on young conifer seedlings, and one method for doing so is plantation release. Release is the practice of treating competing vegetation by reducing the number of plants or their growth. But when should release be employed and for how long? Should it take place immediately after planting or can it be delayed? 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, depending on when the release takes place. One correctly timed release might eliminate the need for a second release and consequently provide an economic benefit.

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Possible clues for answering questions about the critical period of weed control can be found in agriculture (Barrentine 1974, Hall and others 1992, Weaver and Tan 1983). Hall and others (1992), working with grain corn (*Zea mays* L.),[1] for example,

[1]Scientific and common names of trees are from Little (1979), and the scientific and common names of all other vegetation follows the nomenclature of Hickman (1993).

defined when the critical period began, how long it lasted, and the duration of treatment. They also noted that reduced corn leaf area and accelerated senescence of lower leaves were the primary mechanisms affecting yield.

Additional clues can be found in forestry in North America and California. For example, Lauer and others (1993) found that the first 2 continuous years of herbaceous vegetation control gave significantly better loblolly pine (*Pinus taeda* L.) seedling volume growth at age 9 than treating just the first year, and Wagner and others (1999) noted declines in the stem volume of several conifer species in the Great Lakes region of Canada with increasing duration of competition from herbaceous vegetation.

On a good site in northern California, Radosevich (1984) studied the competitive interaction between greenleaf manzanita (*Arctostaphylos patula* E. Greene) and ponderosa pine seedlings in an experiment with varying proportions of seedlings and shrubs. During the first growing season, no interference was observed between shrubs and seedlings, even though about 60 times more growth in terms of biomass took place on the shrubs than on the pines. Interference apparently began during the second growing season. After three growing seasons, shrub growth was still about 35 times that of pine seedling growth. Pine growth had decreased on all plots where manzanita was present. Also, after three seasons, manzanita was beginning to limit its own growth, especially where it was more abundant.

On a poor site in northern California, Fiddler and McDonald (1999) found that treating competing vegetation for the first 3 years and delaying treatment for the first 3 years and treating for the second 3 years both provided statistically larger values for height, diameter, and foliar cover of ponderosa pine seedlings than counterparts in the control after 10 years. Competition came primarily from three aggressive species of shrubs. In another study with ponderosa pine seedlings and aggressive shrub species, again on a poor site in northern California, McDonald and Fiddler (2001) noted that delaying treatment for 3 years produced results equivalent to treating for the first 3 years and that both resulted in significantly larger pine heights and diameters than for seedlings in the control after 10 years. However, delayed release cost more than 2.5 times that of early release.

As part of a National Forest Service administrative study on alternative release methods (Fiddler and McDonald 1984), data in this study, which is on a good site, were gathered from 1988 through 1997 on vegetation developing after site preparation in a control and on vegetation manipulated deliberately by manually grubbing to a 5-ft radius to create different timespans before and after treatment. The timespans or more specifically "vegetation recovery times after disturbance by site preparation and release," were important considerations.

Figure 1—Blooming deerbrush in an opening in the uncut stand, spring 1988.

This paper reports the recovery of several categories of vegetation after treatment and quantifies the survival and growth of ponderosa pine seedlings after immediate and delayed release.

Methods

Location and Site Characteristics

The study area was located in the northern Sierra Nevada Mountains on the Mount Hough Ranger District of the USDA Forest Service's Plumas National Forest in T 24 N, R 9 E, sec. 31, Mount Diablo meridian, about 5 airline miles southwest of Quincy, California. Before the study began, the land was covered with scattered conifers and tall, dense shrubs, probably from a forest fire in the distant past. Vegetation in the area has been placed in the montane and subalpine region of the Sierra Nevada and Cascade Ranges (Rundel and others 1977) and in the Sierra Nevada Mixed Conifer forest vegetation type (Tappeiner 1980). In terms of ecological subregions of California, the area corresponds to section M 261 E. Sierra Nevada and the granitic and metamorphic hills subsection (USDA Forest

Service 1997). Ponderosa pine was the most abundant species, with coast Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) second, and incense-cedar (*Libocedrus decurrens* Torr.) and California white fir (*Abies concolor* var. *lowiana* (Gord.) Lemm.) scattered throughout. Several native California hardwoods, including California black oak (*Quercus kelloggii* Newb.), Pacific dogwood (*Cornus nuttallii* Audubon), and blue elderberry (*Sambucus mexicana* C. Presl.) were represented in the study area, mostly as single trees.

Before the study began, the lower vegetation consisted primarily of 5- to 7-ft tall deerbrush (fig. 1), with scattered plants of mountain whitethorn (*Ceanothus cordulatus* Kellogg), greenleaf manzanita, and bush chinquapin (*Chrysolepis sempervirens* (Kellogg) Hjelmq.). Creeping snowberry (*Symphoricarpos mollis* Nutt.) also was present beneath taller shrubs and in small openings.

Site quality of the study area is above average, with the height of dominant mixed conifers averaging about 70 ft in 50 years (Dunning and Reineke 1933). The soil, which belongs to the Skalan family, is 5 to 6 ft deep and has a sandy loam texture with 30 percent rock fragments. Taxonomically, it is an Ultic Haploxeralf derived from greenstone parent material. The elevation is about 4,500 ft, the slope averages 35 percent, and the aspect is southwest. As a whole, the area is reasonably uniform with respect to slope, aspect, and soil. Precipitation averages 40 in annually, with about 40 percent falling as snow. Annual temperatures range from 5 °F to 95 °F and average 50 °F. The growing season is about 140 days.

The site was prepared for planting by broadcast burning in fall 1987. The area burned “hot,” and almost all the slash, shrub stems, and aboveground organic material were consumed, leaving only blackened stumps, logs, and stubs of the largest shrub clumps.

Ponderosa pine seedlings from a nearby seed source that had been raised for 1 year in the nursery were outplanted in late April 1988. Spacing was 10 by 10 ft. The spring was abnormally cold and wet. Survival of seedlings in all study plots in mid-July was 90 percent.

When the study began, the plant community consisted of sprouts from shrub and hardwood root crowns, plants from dormant seeds in the soil, and plants from windblown seeds. In addition to the planted ponderosa pine seedlings (fig. 2), the early plant community consisted of many species of shrubs and forbs, with the most abundant being those that originated from belowground root collars or rhizomes. Not many graminoids were present during the first growing season. A few deer (*Hemionus* spp.) and several mounds of pocket gophers (*Thomomys* spp.) were noticed in the study area. The pocket gopher population increased slowly, peaked in 1991–92, and declined thereafter.

Figure 2—A typical ponderosa pine seedling in the study area after one full growing season.

Study and Design

The experimental design was completely randomized, with four treatments, including a control, each replicated four times. A replicate (plot) was rectangular and consisted of about 0.1 acre, each of which contained 35 to 40 ponderosa pine seedlings surrounded by one or two rows of buffer (seedlings receiving similar treatment). The study began in 1988 and ended in 1997. Release treatments and dates were:

- **T-first-6:** Release every year for first 6 years (1988–93), develop naturally last 4 years.
- **T-first-3:** Release first 3 years (1988–90), develop naturally last 7 years.
- **T-second-3:** Delay 3 years, release next 3 years (1991–93), develop naturally last 4 years.
- **Control:** No release, develop naturally entire 10 years of study (1988–97).

Release consisted of grubbing all vegetation within a 5-ft radius around pine seedlings with handtools. The goal was to grub vegetation below the root crown to a depth of about 4 ins and not damage pine seedling roots. The initial grubbing took place in May 1988, and subsequent grubbing was performed in late summer or fall. The cost of each treatment, both initially and for retreatment, was calculated from the payroll records of laborers paid at the Wage Grade 1 rate (U.S. Department of Labor 1993) of $8.74 per hour. No allowance for travel, equipment, or overhead was included.

Sampling

Of the 35 to 40 ponderosa pine seedlings in each plot, 25 that appeared to have good potential of becoming future crop trees were selected and tagged. Chlorotic and misshapen seedlings that would be removed in a precommercial thinning were excluded. Stem diameter (measured at 12 in above mean ground line), stem height, foliar cover (the sum of shadows that would be cast by the leaves and stems of individual species expressed as a percentage of the land surface [Daubenmire 1968]), and needle length were measured on each seedling. Unfortunately, limitations in budget and staffing affected the amount of sampling that was done, and some remeasurements were not taken. The seedlings were periodically checked for injury from animals, insects, and weather.

The sampling intensity for evaluating natural vegetation was five subplots in each plot. The subplots were square and centered around randomly selected pine seedlings. The subplots encompassed 1 milacre (0.001 acre or 43.56 ft^2). The most abundant species and categories of vegetation were evaluated for density, foliar cover, and average dominant height (average of the three tallest stems per subplot measured from mean ground line to bud). More specifically, the number of plants in each subplot was counted, foliar cover was visually estimated, and height was measured with a graduated pole. Values of foliar cover were checked by a foot-square wire frame and occasionally with a metal tape. In some instances, "plant" was difficult to define. Thus, each fern frond and each clump of hardwoods or shrubs was counted as one plant. As for pine seedlings, all vegetation was checked periodically for injury and causal agent.

The 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 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.

To quantify plant diversity, new species were noted on study plots at each visit, and all species were recorded when the study began and ended.

Table 1–Natural vegetation in study plots, 1988–1997

Species	1988	1997	Common names
Conifers:	–[1]	–	
Hardwoods:			
Cornus nuttallii Audubon	X[1]	X	Pacific dogwood
Quercus kelloggii Newb.	X	X	California black oak
Sambucus mexicana C. Presl.	X	X	Blue elderberry
Shrubs:			
Amelanchier utahensis Koehne	X	X	Utah service-berry
Arctostaphylos patula E. Greene	X	X	Greenleaf manzanita
Ceanothus cordulatus Kellogg	X	X	Mountain whitethorn
Ceanothus integerrimus Hook. & Arn.	X	X	Deerbrush
Ceanothus prostratus Benth.	X	X	Mahala mat
Chrysolepis sempervirens (Kellogg) Hjelmq.	X	–	Bush chinquapin
Penstemon spp.	X	X	Beardtongue
Penstemon spp.[2]	X	X	Beardtongue
Ribes spp.	X	X	Gooseberry
Rosa gymnocarpa Nutt.	X	X	Wood rose
Rubus parviflorus Nutt.	X	X	Thimbleberry
Symphoricarpos mollis Nutt.	X	X	Snowberry
Forbs:			
Adenocaulon bicolor Hook.	X	X	Trail plant
Agoseris grandiflora (Nutt.) E. Greene	X	X	Bigflower agoseris
Apocynum androsaemifolium L.	X	X	Spreading dogbane
Aster radulinus A. Gray	X	X	Roughleaf aster
Balsamorhiza deltoidea Nutt.	X	–	Deltoid balsamroot
Castilleja spp.	X	X	Indian paintbrush
Cirsium vulgare (Savi) Ten.	X	X	Bull thistle
Clarkia rhomboidea Douglas	X	X	Diamond clarkia
Convolvulus arvensis L.	X	X	Bindweed
Epilobium spp.	X	X	Willow herb
Erigeron inornatus A. Gray	X	X	California rayless fleabane
Galium spp.	X	X	Bedstraw
Gayophytum diffusum Torrey & A. Gray	X	X	Spreading groundsmoke
Gnaphalium luteo-album L.	X	X	Cudweed
Iris spp.	X	X	Iris
Lactuca serriola L.	X	X	Prickly lettuce
Lilium washingtonianum Kellogg	X	X	Washington lily
Madia gracilis (Smith) Keck	X	X	Slender tarweed
Mimulus spp.	X	–	Monkeyflower
Montia parvifolia (DC.) E. Greene	X	X	Littleleaf minerslettuce
Osmorhiza chilensis Hook. & Arn.	X	–	Sweet cicely
Phacelia spp.	X	X	–
Potentilla spp.	X	X	Cinquefoil
Smilacina racemosa (L.) Link	X	–	False Solomon's seal
Stephanomeria lactucina A. Gray	X	X	Lettuce wirelettuce
Tragopogon dubius Scop.	X	X	Yellow salsify
Viola spp.	X	X	Voilet
Unidentified	X	X	–
Graminoids:			
Achnatherum spp.	–	X	Needlegrass
Bromus spp.	X	X	Brome
Carex spp.	X	X	Sedge
Elymus glaucus Buckley	–	X	Blue wildrye
Unidentified	–	X	–
Fern			
Pteridium aquilinum (L.) Kuhn var. *pubescens* L. Underw.	X	X	Bracken

[1] X = present, – = absent.
[2] Two species of *Penstemon*.

Results

Plant Diversity

The natural plant community on all study plots (including control) near the beginning of the study in 1988 consisted of no natural conifer species, 3 species of hardwoods, 12 shrubs, 28 forbs, 2 graminoids (grasses and sedges), and 1 fern, for a total of 46 species (table 1). By the end of the study, vegetation in the study plots included no natural conifer seedlings, 3 hardwoods, 11 shrubs, 24 forbs, 5 graminoids, and 1 fern, for a total of 44 species. Plant diversity also was evaluated by treatment at the end of the study, but only on the subplots. The number of species by treatment was T-first-6, 19; T-first-3, 31; T-second-3, 27; and control, 31. Data and diary records emphasized the rapidity of revegetation in the study area and the high diversity of the new plant community. Indeed, the diary record of July 14, 1988 noted: "The amazing part of this study is the tremendous increase in plant cover" (fig. 3A, B).

Deerbrush

Deerbrush colonized aggressively. As early as May 9, 1988, deerbrush plants from root crowns and dormant seeds in the soil were evident throughout the study area. Diary records in mid-July indicated that it was difficult to tell the difference between recently grubbed plots and the control. In spite of many deer sightings, deerbrush was never more than lightly browsed during the study. Average density of deerbrush in the control in 1988 was 21,500 plants per acre, which then declined to 6,100 plants per acre at the end of the study in 1997 (table 2), a 72-percent decrease. Foliar cover and height increased steadily and reached 22,700 ft^2 per acre and 6.4 ft tall respectively, which were 17 and 13 times first-year (1988) values.

Among treatments, deerbrush in the control plots had significantly higher density (6,100 plants per acre) than those treated for the first 3 years (1,100 plants per acre) or the second 3 years (850 plants per acre) at the end of the study (table 4). The trend in foliar cover was similar, with plants in the T-first-3 treatment (8,400 ft^2 per acre) and T-second-3 treatment (3,700 ft^2 per acre) having significantly lower average values than those in the control (22,700 ft^2 per acre). Although not statistically significant, the higher density and foliar cover of deerbrush in the T-first-3 treatment relative to the T-second-3 treatment indicated vigorous recruitment and subsequent growth of new seedlings after the first 3 years. Almost all these plants originated from dormant seeds in the soil. Average height of deerbrush ranged from 5.5 to 6.4 ft and did not differ statistically among treatments at the end of the study.

3A

3B

Figure 3—An overview of the study area on (A) May 9, 1988, and (B) July 9, 1988. Note the large increase in deerbrush density and cover.

Other Shrubs

Of the 11 shrub species other than deerbrush that were present in the study area, the two species of beardtongues (*Penstemon* sp.) and creeping snowberry were the most abundant and the most evenly distributed. The beardtongues probably originated from dormant seeds in the soil, and some plants of creeping snowberry could have

Table 2–Average density, foliar cover, and height, with standard errors (SE), of deerbrush, other shrubs, forbs, and graminoids in the control, northern California, 1988–1997

Species	Year	Density	SE	Cover	SE	Height	SE
		No. of plants/acre		*Square feet/acre*		*Feet*	
Deerbrush	1988	21,500	2,636	1,300	238	0.5	0.1
	1990	8,250	763	6,350	556	2.6	0.3
	1991	8,350	750	10,750	1,438	2.6	0.3
	1993	6,350	741	16,750	1,541	4.0	0.2
	1997	6,100	794	22,700	1,343	6.4	0.5
Other shrubs	1988	10,050	3,331	1,950	574	0.4	0.1
	1990	3,900	911	1,900	311	1.1	0.2
	1991	4,750	1,466	2,050	427	0.8	0.1
	1993	3,400	616	1,400	383	1.1	0.1
	1997	2,550	126	1,850	506	1.5	0.1
Forbs	1988	33,450	9,362	2,150	512	0.8	0.1
	1990	52,200	18,740	2,350	574	1.7	0.3
	1991	69,650	16,528	2,800	712	1.9	0.1
	1993	46,450	10,028	2,100	1,002	2.2	0.1
	1997	27,300	10,908	2,450	1,109	2.4	0.2
Graminoids	1988	3,050	1,312	50	50	0.8	0.3
	1990	1,150	544	50	50	1.4	0.5
	1991	2,050	759	100	58	0.9	0.1
	1993	1,800	627	150	96	2.0	0.8
	1997	5,800	2,634	150	150	2.1	0.6

as well. However, the large central stem and extensive root system of the creeping snowberry suggest that most plants probably resprouted after the broadcast burn. The other species in this category were barely represented and widely scattered. Indeed, one shrub, bush chinquapin, could not be found at the end of the study.

In the control, the initial average density of other shrubs was high (10,050 plants per acre) and then declined erratically by 75 percent to 2,550 plants per acre at the end of the study (table 3). The trend in foliar cover was similar, with an overall slight decline (1,950 to 1,850 ft^2 per acre). Average height increased from 0.4 to 1.5 ft during the study.

Among treatments, the average densities of other shrubs in T-first-3 (700 plants per acre) and T-second-3 (900 plants per acre) were significantly lower than that in the control (2,550 plants per acre, table 3). Time since disturbance did not appear to be a factor affecting average foliar cover or height because they did not differ statistically from the control. Foliar cover ranged from 450 to 1,850 ft^2 per acre, and height from 1.4 to 1.6 ft (table 4).

Forbs

The forb component of the plant community, in addition to being unusually diverse soon after site preparation, was initially composed of perennial species like roughleaf aster (*Aster radulinus* A. Gray) (fig. 4A) and lettuce wirelettuce (*Stephanomeria lactucina* A. Gray) that originated from rhizomes, and others like bindweed (*Convolvulus arvensis* L.) (fig. 4B) and spreading dogbane (*Apocynum androsaemifolium* L.) that had deep, persistent roots. A host of early annual

Table 3–Average density, foliar cover, and height of deerbrush, other shrubs, forbs, and graminoids among treatments, northern California, 1997

Species	Treatment	Density	Cover	Height
		No. of plants/acre	*Square feet/acre*	*Feet*
Deerbrush	Treated first 6 years	–[1]	–	–
	Treated first 3 years	1,100 a[2]	8,400 a	6.4 a
	Treated second 3 years	850 a	3,700 a	5.5 a
	Control	6,100 b	22,700 b	6.4 a
	Standard error[3]	4.63	2,164.36	0.77
	F ratio[3]	35.52	20.91	.49
	P value[3]	.0001	.0004	.6268
Other shrubs	Treated first 6 years	–	–	–
	Treated first 3 years	700 a	450 a	1.6 a
	Treated second 3 years	900 a	700 a	1.4 a
	Control	2,550 b	1,850 a	1.5 a
	Standard error	4.44	440.33	.47
	F ratio	9.78	2.88	.04
	P value	.0055	.1083	.9572
Forbs	Treated first 6 years	–	–	–
	Treated first 3 years	19,350 a	1,100 a	2.1 a
	Treated second 3 years	30,250 a	900 a	1.9 a
	Control	27,300 a	2,450 a	2.4 a
	Standard error	20.58	729.35	.27
	F ratio	.61	1.34	.80
	P value	.560	.3103	.4792
Graminoids	Treated first 6 years	–	–	–
	Treated first 3 years	14,350 a	250 a	2.7 a
	Treated second 3 years	5,550 a	200 a	2.7 a
	Control	5,800 a	150 a	2.1 a
	Standard error	29.19	147.20	.54
	F ratio	.21	.12	.48
	P value	.8139	.8923	.6358

[1] Vegetation that became established after 6 years was judged as having little or no competitive effect on the pine seedlings. Hence it was not quantified.

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

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

4A

4B

Figure 4—Perennial forbs that originated from (A) rhizomes (*Aster radulinus*) and (B) deep, persistent roots (*Convolvulus arvensis*).

species like bull thistle (*Cirsium vulgare* [Savi] Ten.), a species of willow herb (*Epilobium* spp.), spreading groundsmoke (*Gayophytum diffusum* Torrey and A. Gray), prickly lettuce (*Lactuca serriola* L.), slender tarweed (*Madia gracilis* (Smith) Keck), and others that arose from dormant or windblown seeds also colonized the area. Initially, the distribution of these species was clumpy, but with time the aggregations expanded widely.

In the control, large numbers of forbs were present initially (33,450 plants per acre), peaked in 1991 (69,650 per acre), and then decreased in 1997 (27,300 plants per acre) (table 3). Average foliar cover followed the same trend, peaking in 1991 at 2,800 ft^2 per acre, and then declining at the end of the study to 2,450 ft^2 per acre.

The overall gain in foliar cover during the study was 14 percent. Average height of forbs steadily increased from 0.8 ft in 1988 to 2.4 ft in 1997.

Among treatments, the average density of forbs was highest in the T-second-3 treatment (30,250 plants per acre) and lowest in the T-first-3 treatment (19,350 per acre), with the control being intermediate (27,300 plants per acre) (table 4). Foliar cover and height were both lowest in the T-second-3 treatment and highest in the control. No statistically significant difference among treatments was found for forb density, foliar cover, or height.

Graminoids

Except for a few plants of *Bromus* and *Carex*, the number of graminoids and their development lagged behind most of the other plant species that invaded the study area. Many small plants that were present initially died, and graminoid density decreased during the first 3 years. More grass species became present about this time, especially a species of needlegrass (*Achnatherum* sp.) and blue wildrye (*Elymus glaucus* Buckley). By 1997, the graminoids had increased appreciably and were exceeding their initial (1988) levels of density, foliar cover, and height.

Graminoids in the control numbered more than 3,000 per acre in 1988, but had only a minor amount of foliar cover and were relatively short (table 3). After a 62-percent decrease in 1990, graminoid density generally increased through 1993 and then jumped threefold in 1997 to 5,800 plants per acre. Foliar cover and height generally increased from low levels initially to 150 ft^2 per acre and 2.1 ft, respectively, in the control at the end of the study.

Among treatments in fall 1997, average density, foliar cover, and height of graminoids in the T-first-3 treatment were larger or equal to those in the T-second-3 or control (table 4), although not statistically different at the 5-percent level. Average density ranged from 5,550 to 14,350 plants per acre, foliar cover from 150 to 250 ft^2 per acre, and height from 2.1 to 2.7 ft.

Ponderosa Pine

Early pine seedling mortality apparently was caused by low seedling vigor, middle-year mortality by pocket gophers, and later-year death by drought-induced suppression. Percentage of survival by treatment at the end of the study was:

Treatment	Average	Standard error
T-first-6	74	7
T-first-3	74	3
T-second-3	76	6
Control	66	6

At the end of the study in 1997, average stem diameter and foliar cover of pines in all treatments differed statistically from those in the control.

Altogether, 134 of approximately 450 seedlings died, resulting in a survival rate of 70 percent. Analysis of variance of transformed (arcsin) percentages indicated no significant difference in survival rate among treatments.

Statistically significant differences among treatments for ponderosa pine seedlings first became evident four growing seasons after planting (fall 1991) when average stem diameter of the seedlings in the T-first-6 and T-first-3 treatments differed statistically from that of the seedlings in the control (table 5). Annual height growth of treated seedlings was beginning to accelerate (fig. 5). Average foliar cover of seedlings in the T-first-3 treatment also differed from counterparts in the control. At the end of the study in 1997, average stem diameter and foliar cover of pines in all treatments differed statistically from those in the control. Neither average height nor needle length, which was used as an indicator of future treatment effectiveness (McDonald and others 1992), differed statistically among treatments during the 10-year study.

At the end of the study, average height of ponderosa pine seedlings ranged from 5.6 ft in the control to 7.7 ft in the T-first-6 treatment; stem diameter varied from 2.0 in in the control to 3.7 in in the T-first-6 treatment; and average foliar cover ranged from 5,650 ft^2 per acre in the control to more than 21,000 ft^2 per acre among treatments (table 5).

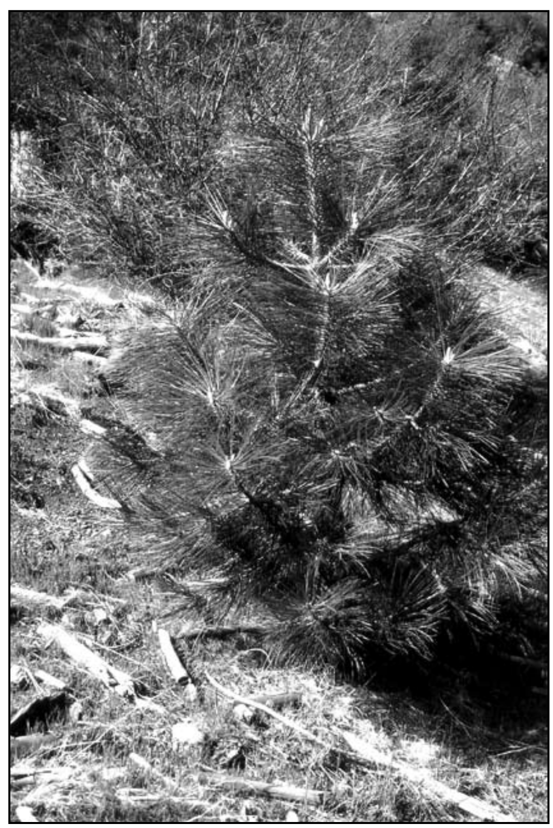


Figure 5—A representative 6-year-old ponderosa pine seedling that has been grubbed for the first 6 years, April 1994.

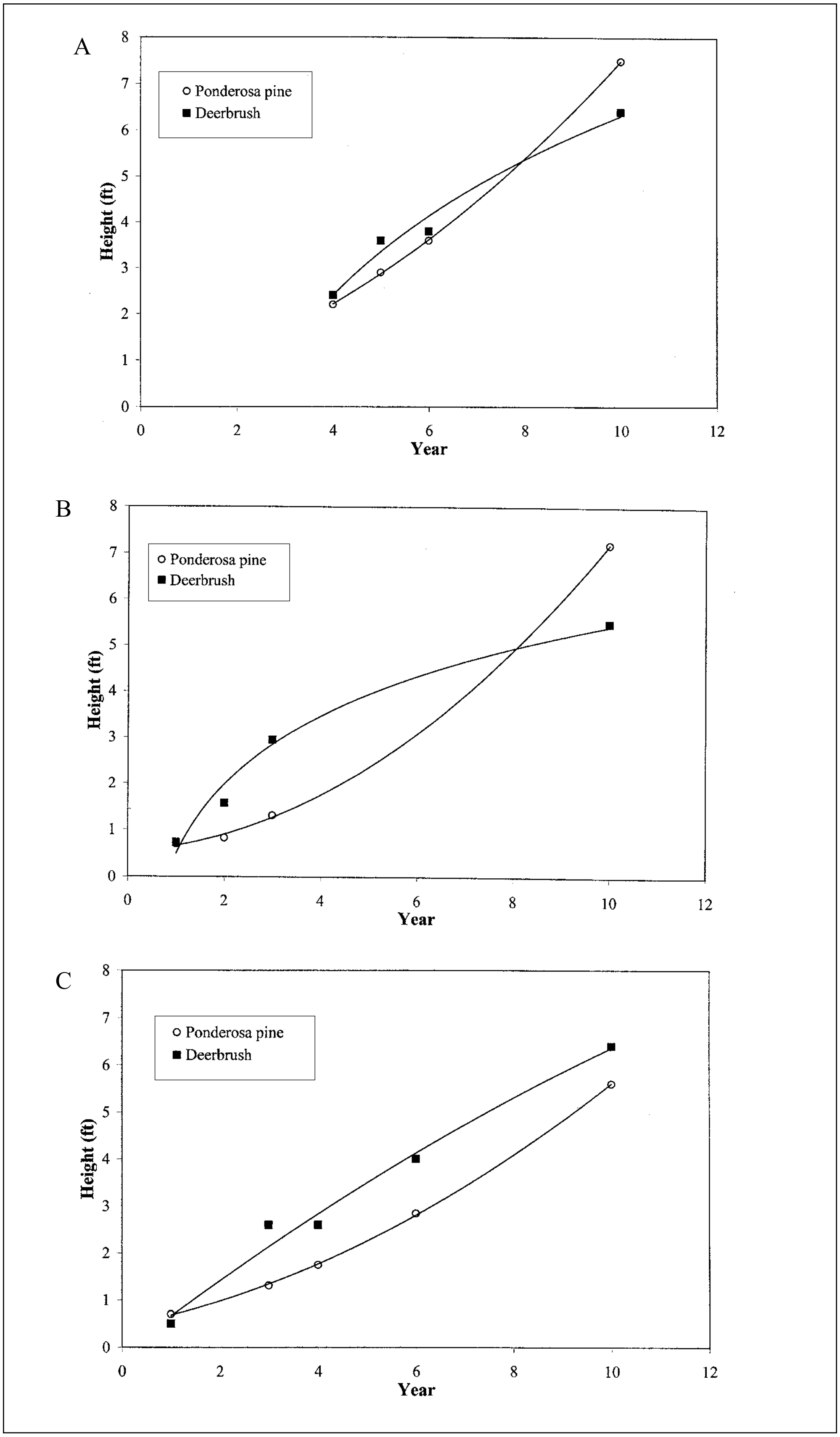
Table 4–Average stem height, diameter, foliar cover, and needle length of ponderosa pine seedlings, by treatment, northern California, 1988–1997

Treatment	1988	1990	1991	1993	1997
			Height (*feet*):		
Treated first 6 years	0.73 a[1]	1.54 a	2.18 a	3.70 ab	7.68 ab
Treated first 3 years	.68 a	1.52 a	2.16 a	3.60 ab	7.46 ab
Treated second 3 years	.70 a	1.31 a	1.75 a	3.20 ab	7.24 ab
Control	.70 a	1.30 a	1.74 a	2.84 b	5.56 b
Standard error	.15	.09	.11	.21	.56
F ratio	1.08	2.12	4.53	4.17	3.08
P value	.401	.128	.053	.018	.049
			Diameter (*inches*):		
Treated first 6 years	–	–	.74 a	1.62 a	3.68 a
Treated first 3 years	–	–	.72 a	1.43 a	3.23 a
Treated second 3 years	–	–	.56 ab	1.42 ab	3.50 a
Control	–	–	.48 b	.93 b	2.01 b
Standard error	–	–	.05	.11	.27
F ratio	–	–	6.74	7.06	7.57
P value	–	–	.003	.002	.002
			Foliar cover (*square feet/acre*):		
Treated first 6 years	–	–	–	–	21,082 a
Treated first 3 years	–	–	2,650 a	7,800 a	20,250 a
Treated second 3 years	–	–	–	–	20,850 a
Control	–	–	1,000 b	1,850 b	5,650 b
Standard error	–	–	358	1,430	3,047
F ratio	–	–	10.64	8.85	5.08
P value	–	–	.017	.025	.009
			Needle length (*inches*):		
Treated first 6 years	–	.46 ab	.39 ab	.52 ab	–
Treated first 3 years	–	.44 ab	.40 ab	.49 ab	–
Treated second 3 years	–	.42 b	.38 ab	.52 ab	–
Control	–	.42 b	.36 b	.44 b	–
Standard error	–	.01	.01	.02	–
F ratio	–	4.14	2.91	2.96	–
P value	–	.019	.054	.055	–

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

To better portray the relationship between ponderosa pine seedlings and deerbrush, the average heights of the two species were compared graphically for the T-first-3 treatment (fig. 6A), T-second-3 treatment (fig. 6B), and the control (fig. 6C). For the two treatments, deerbrush grew taller initially but then was surpassed by the pines. The respective slopes of the curves at age 10 suggest that the growth of pine will outstrip that of deerbrush in the near future. In the control, the deerbrush stems were taller than ponderosa pine seedlings throughout the 10-year period, but the respective slopes suggest that pine height may slowly catch up to, or even exceed, that of deerbrush.

Figure 6—Relationship between ponderosa pine seedling height and deerbrush stem height for the T-first-3 treatment (A), T-second-3 treatment (B), and control (C).



Production and Cost

Initial grubbing to a 5-foot radius in May 1988 took only a small amount of time, but needed to be done twice. Time to grub thereafter was minimal. The fourth year (1991) was the most costly year for grubbing because many plants, particularly shrubs, had stems that leaned into the subplots and had expanded their root crowns into them. These required additional labor to remove. Later grubbing in 1992 and 1993 took less time each year in each treatment. The most time-consuming treatment was the initial grubbing in the T-second-3 plots. It took 60 hours for the crew to remove the well-established vegetation. Total time to grub the treatments and the corresponding cost were:

Treatment	Time (hours)	Cost per acre (dollars)
T-first-6	65.5	238
T-first-3	27.0	197
T-second-3	82.0	598

The high cost of the T-second-3 treatment was caused not only by the high density of the vegetation, but also by its development belowground. The large burls of California black oak and deerbrush, most of which had survived the broadcast burn, had to be split first and then the roots removed. Grubbing creeping snowberry and bindweed also was difficult and time consuming because the roots were large and the root systems were connected in a radius of 2.5 ft or more. Snowberry plants also were connected aboveground by runners. Bracken fern, *Aster radulinus*, and *Stephanomeria lactucina* had deep, extensive, and rhizomatous root systems, which were almost impossible to remove completely. Other forbs, especially from the genera *Cirsium*, *Clarkia*, *Epilobium*, *Gayophytum*, *Lactuca*, *Madia*, *Mimulus*, and *Viola*, had an inexhaustible seed supply, and grubbing seemed to stimulate more plants than were removed. Needlegrass (*Achnatherum* sp.) and brome (*Bromus* sp.) required loosening around the edges before the main clump could be removed.

The high cost of the T-second-3 treatment was caused not only by the high density of the vegetation, but also by its development belowground.

Discussion and Conclusions

A major reason for analyzing and presenting the results of this study in terms of time since harvest and duration of treatments was to reinforce the hypothesis, based on findings in earlier studies (McDonald and Fiddler 1990, 1995), that early release is more cost-effective than repeated release or delayed release. Delayed release almost always results in more and larger competing plants, often with large, deep masses of roots. The T-first-3 and T-second-3 treatments in this study were a direct test of early versus delayed release. Biologically, these two treatments did not

When a competitive species invades each year for several years, and the duration of treatment is short, early treatment is only marginally effective because a competing species has time to become reestablished before all favorable microsites are occupied.

No release, as in the control, cost nothing economically but permitted the plant community to thrive at the expense of the ponderosa pine seedlings.

significantly differ from each other in terms of pine seedling growth. But economically they did. The cost of manual grubbing in the T-second-3 treatment was more than three times of that in the T-first-3 treatment.

Why was the T-first-3 treatment not biologically more effective than the T-second-3 treatment for promoting ponderosa pine seedling growth? Strong competition in the T-first-3 treatment, particularly from deerbrush, is a likely answer. In spite of zealous grubbing, parts of some clumps sprouted and dormant seeds in the soil germinated year after year. The result was a relatively high density of plants soon after each treatment ended and a concomitant drain on site resources. When a competitive species invades each year for several years, and the duration of treatment is short, early treatment is only marginally effective because a competing species has time to become reestablished before all favorable microsites are occupied. As shown in table 4, the average density, foliar cover, and height of deerbrush at the end of the study was higher in the T-first-3 treatment than in the T-second-3 treatment, even though not statistically different. Plainly, the early, short-duration treatment with 7 years of recovery time (1991–97) provided no gain in pine seedling growth over the treatment that had a later beginning and 4 years of recovery time (1994–97).

Releasing each year for the first 6 years, as in the T-first-6 treatment, was statistically no more advantageous to pine seedling development than treating for the first 3 years and was 21 percent more expensive to implement.

No release, as in the control, cost nothing economically but permitted the plant community to thrive at the expense of the ponderosa pine seedlings. In the control, both average foliar cover and height of deerbrush were greater than that of pine seedlings (22,700 versus 5,650 ft^2 per acre and 6.4 versus 5.6 ft, respectively).

When both the biological findings and cost information in this study are considered, the most cost-effective treatment for releasing ponderosa pine seedlings would be to treat every year for the first 3 years (T-first-3) and do nothing thereafter. Also, the remarkable similarity in pine diameter and foliar cover among treatments and their significant difference from the control are of note. And the widening difference in height growth rates between pine seedlings and deerbrush at age 10 (fig. 6 A,B) should be considered. On the basis of this information, ponderosa pine seedlings in this environment should be released, but when, and for how long are unimportant.

During this 10-year study, the plant community was composed of a maximum of 49 species; 46 at the beginning of the study and 44 at the end. Relative to other young plantations in our National Forest Service administrative study, 49 species places it second in terms of species richness. The range was 13 to 61 species (McDonald and Fiddler 2006).

Early and sustained colonization by a large number of species in several categories is not unusual on an above-average site, as in this study, where site resources are plentiful and the growing season is relatively long. At the end of the study, more than 41,000 plants per acre were present in the treatments from which the data were taken, with 65 percent being forbs. Although the forbs dominated in terms of density, deerbrush excelled in foliar cover, with 84 percent of total cover. Deerbrush also dominated in average height, being more than twice as tall as other categories of natural vegetation at the end of the study.

Three trends in the plant community, one expected, and two not expected, were noteworthy. We anticipated the late surge of the graminoids but did not expect the contribution of the other shrubs to be as small as it was, and we did not anticipate the smaller number of species on the most intensively treated plots.

By the end of the study in 1997, the graminoids had increased greatly, although erratically, in average density and height. This was caused by the invasion of taller and more aggressive grasses and by their ability to compete in an increasingly crowded plant community with decreasing levels of site resources. Similar findings were found on both an above-average site (McDonald 1999) and a below-average site (Fiddler and McDonald 1999).

Average density, foliar cover, and height of the 11 other shrubs combined were generally lower than for other categories of vegetation in all treatments at the end of the study. Although several of these species are notably aggressive, they may not be as aggressive as deerbrush. In a direct comparison of planted deerbrush and greenleaf manzanita in another study (McDonald and others 1998), deerbrush had significantly more stems, was taller, and had wider crowns than manzanita after two growing seasons. This relationship continued throughout the 4-year study. In addition, deerbrush developed a clump of stems 1 year sooner than manzanita and began producing flowers and setting seed at age 3, whereas manzanita did not flower during the study.

The lower species richness in the T-first-6 treatment relative to the other treatments and the control probably can be explained by the uninhibited ability of the ponderosa pine seedling roots to capture site resources belowground and the rapid enlargement of crowns aboveground. Propagules of other species apparently found it hard to invade this environment or difficult to become established once there.

The density and developmental trends in the control suggest the composition and growth of the plant community in the near future in the absence of release.

Many pines remain, and although not growing as fast as their counterparts in the treated plots, some will persist and gradually overtop the competing vegetation. Deerbrush will thrive. With 6,100 plants per acre, 22,700 ft^2 per acre of foliar cover, and 6.4 ft of height after 10 years, deerbrush clearly is, and will continue to be, the dominant lesser vegetation in the plantation. A few of the other shrubs will be relegated to small openings among the deerbrush plants, but most will be under them. The forbs will share the same fate, with a trend toward fewer species and a slow increase in perennials (McDonald 1999). The role of the graminoids in the future plant community is unknown. That they have competed well so far suggests that they will at least maintain their presence in the near future.

On released plots, the plant community of the near future will consist of more and larger pines than in the control, and they will place more stress on the other species faster. Consequently, the community of the future will be mostly pines and deerbrush, with a few other shrubs, forbs, and graminoids among them.

English Equivalents

When you know:	**Multiply by:**	**To get:**
Inches (in)	2.54	Centimeters
Feet (ft)	.3048	Meters
Acres	.405	Hectares
Milacre	4.05	Square meters
Square feet per acre (ft^2/acre)	.23	Square meters per hactare
Degrees Fahrenheit (°F)	$\frac{F-32}{1.8}$	Degrees Celsius

References

Barrentine, W.L. 1974. Common cocklebur competition in soybeans. Weed Science. 22: 600–603.

Connell, J.H.; Slatyer, R.O. 1977. Mechanisms of succession in natural communities and their role in community stability and organization. American Naturalist. 111: 1119–1144.

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

De Groot, J. 1991. Yield of ponderosa pine seedlings following broadcast and spot hexazinone applications. Moscow, ID: University of Idaho. M.S. thesis.

Dunning, D.; Reineke, L.H. 1933. Preliminary yield tables for second-growth stands in the California pine region. Tech. Bull. 354. Washington, DC: U.S. Department of Agriculture, Forest Service. 24 p.

Fiddler, G.O.; McDonald, P.M. 1984. Alternatives to herbicides in vegetation management: a study. In: Proceedings, 5th annual forest vegetation management conference. Redding, CA: Forest Vegetation Management Conference: 115–126.

Fiddler, G.O.; McDonald, P.M. 1999. Treatment duration and time since disturbance affect vegetation development in a young ponderosa pine plantation. Res. Note PSW-RN-424. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 8 p.

Grime, J.P. 1979. Plant strategies and vegetation processes. New York: John Wiley and Sons. 222 p.

Hall, M.R.; Swanton, C.J.; Anderson, G.W. 1992. The critical period of weed control in grain corn (*Zea mays*). Weed Science. 40: 441–447.

Hickman, J.C., ed. 1993. The Jepson manual, higher plants of California. Berkeley, CA: University of California Press. 1400 p.

Lauer, D.K.; Glover, G.R.; Gjerstad, D.H. 1993. Comparison of duration and method of herbaceous weed control on loblolly pine response through midrotation. Canadian Journal of Forest Research. 23: 2116–2125.

Little, E.L., Jr. 1979. Checklist of United States trees (native and naturalized). Agric. Handb. 541. Washington, DC: U.S. Department of Agriculture, Forest Service. 375 p.

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

McDonald, P.M.; Fiddler, G.O. 1990. Ponderosa pine seedlings and competing vegetation: ecology, growth, and cost. Res. Pap. PSW-199. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 10 p.

McDonald, P.M.; Fiddler, G.O. 1993. Feasibility of alternatives to herbicides in young conifer plantations in California. Canadian Journal of Forest Research. 23: 2015–2022.

McDonald, P.M.; Fiddler, G.O. 1995. Development of a mixed-shrub-ponderosa pine community in a natural and treated condition. Res. Pap. PSW-224. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 18 p.

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

McDonald, P.M.; Fiddler, G.O. 2006. Plant species diversity in young conifer plantations in northern and central California. Western Journal of Applied Forestry. 21(1): 49–54.

McDonald, P.M.; Laurie, W.D.; Hill, R. 1998. Early growth characteristics of planted deerbrush and greenleaf manzanita seedlings in California. Res. Note PSW-RN-422. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 6 p.

McDonald, P.M.; Skinner, C.N.; Fiddler, G.O. 1992. Ponderosa pine needle length: an early indicator of release treatment effectiveness. Canadian Journal of Forest Research. 22: 761–764.

Radosevich, S.R. 1984. Interference of shrub and tree species: a research approach. 11 pages, Unpublished draft. On file with: Philip McDonald, 3644 Avetech Parkway, Redding, CA 96001.

Rundel, P.W.; Parsons, D.J.; Gordon, D.T. 1977. Montane and subalpine vegetation of the Sierra Nevada and Cascade Ranges. In: Barbour, M.G.; Major, J., eds. Terrestrial vegetation of California. New York: John Wiley and Sons: 559–599.

SAS Institute, Inc. 1988. SAS procedures guide, release 6.03 edition. Cary, NC: SAS Institute, Inc. 441 p.

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

Tappeiner, J.C., II. 1980. Sierra Nevada mixed conifer. In: Eyre, F.H., ed. Forest cover types of the United States and Canada. Washington, DC: Society of American Foresters: 118–119.

U.S. Department of Agriculture, Forest Service [USDA Forest Service]. 1997. Ecological subregions of California, section and subsection descriptions. R5-EM-TP-005. San Francisco, CA: Pacific Southwest Region. 5. p. Chapter 9.

U.S. Department of Labor, Employment Standards Administration, Wage and Hour Division. 1993. Register of wage determinations under the service contract act. Wage determination No. 1977–0727, Revision No. 18. June. Washington, D.C.

Wagner, R.G.; Mohammed, G.H.; Noland, T.L. 1999. Critical period of interspecific competition for northern conifers associated with herbaceous vegetation. Canadian Journal of Forestry Research. 29: 890–897.

Weaver, S.E.; Tan, C.S. 1983. Critical period of weed interference in transplanted tomatoes (*Lycopersicon esculentum*). Weed Science. 31: 476–481.

Pacific Southwest Research Station

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