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Response of Young Ponderosa Pines, Shrubs, and Grasses to Two Release Treatments

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Through natural selection over thousands of years, many species of shrubs and grasses are superbly adapted to dominate in newly disturbed areas. In many instances, they are better adapted than the nursery-grown pines and firs that are outplanted over the landscape, minus part of their root systems.[1] Bearclover (*Chamaebatia foliolosa* Benth) and cheatgrass (*Bromus tectorum* L.) are two such species.

Bearclover is an evergreen perennial shrub that is prevalent between the 1,000- to 6,000-foot elevation in the central Sierra Nevada of California. It excels on south slopes and in open stands. In the typical California environment of summer drought and limited soil moisture, the root system of bearclover is key to its success as a species. The root system consists of an extensive network of roots and rhizomes 4 to 16 inches below the soil surface with sinker roots that often extend to depths of 6 feet. After fire or other disturbance, the plants resprout from adventitious buds at nodes along the rhizomes, and produce a dense stand. Additional competitive mechanisms include capability to fix nitrogen,[2] to reproduce from seed, and potential for allelopathy.[3]

Bearclover is a serious competitor to conifer regeneration. Indeed, if bearclover is present, survival and growth of conifer seedlings is poor,[4,5,6] and the plantation often fails.

Cheatgrass is an introduced annual species that invaded North America from Eurasia in the 1889-1894 period and by 1928 had spread throughout what is now its naturalized range.[7] It has several adaptations that allow it to effectively colonize and become established in disturbed areas. It produces huge seedcrops, has an extensive root system, a high root-shoot ratio, capability for growth in cold soils, and matures early in the growing season.[8] Because survival is high and appears to be independent of density,[9] cheatgrass tends to saturate an area. A community of low diversity often results.

Because of its many and effective adaptations to a wide range of environmental conditions, cheatgrass can be a major cause of failure in conifer plantations. However, if the soil is deep, and the newly planted conifer seedlings are provided 1 or 2 years of competition-free growth, their roots can occupy the deeper soil layers, stay in a zone of adequate moisture, and increase in number and volume. Dense stands of grasses can exclude more aggressive shrub species if the grasses become established first.[10]

This note reports a study in central California on the response of young ponderosa pines, bearclover, and cheatgrass to two

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To release a young pine plantation on a medium site in central California, herbicides and mulches were applied soon after planting to study their effectiveness. Bearclover is an aggressive shrub species that resprouts from rhizomes after disturbance, and must be controlled if young conifer seedlings are to become established. After 4 years, resprouting bearclover plants numbered 282,000 per acre in the control, but less than 4,000 per acre in the plots treated by herbicides. Mean foliar cover was 63 percent versus 1 percent for control and herbicide plots, respectively. Ponderosa pine seedlings were significantly taller, had larger mean diameters, and survived better in the herbicide treatment than counterparts in mulched plots and control. The 5-foot square mulches were ineffective for controlling bearclover. Cheatgrass invaded the plantation in the second year, and after 2 more years became abundant in herbicide plots (743,667 plants per acre) and plentiful in the control (130,300 plants per acre).

Retrieval Terms: competition, plant development, northern California, replacement species, vegetation management

release treatments—applying herbicides and a mulch—and their effect on the capability of planted pines to become established and develop well.

Methods

The study area was located on the Eldorado National Forest's Amador Ranger District, about 35 miles northeast of Jackson, California. Before logging, it was primarily a dense stand of bearclover with large ponderosa pines (*Pinus ponderosa* Dougl. ex Laws. var. *ponderosa*) scattered throughout. An occasional blackened stump suggested that the area had burned previously. After logging, the site was prepared for planting by broadcast burning in early March 1991. The foliage of bearclover had enough oils and aromatic chemicals to burn in the winter after a period of warm dry weather. After burning, almost all vegetation was consumed, and the surface was mostly mineral soil with only stubs of bearclover remaining aboveground.

Ponderosa pine seedlings (1-0) from a local seed source were grown in the USDA Forest Service's nursery at Placerville, Calif., and planted by auger in March 1991 at a 10- by 10-foot spacing. Pine seedling height averaged 0.6 feet above mean ground line.

Site quality of the study area is medium with height of dominant ponderosa pines averaging about 40 feet in 50 years.[11] The soil, which is closely related to the Chaix series, was formed from material weathered from granitic rock. Taxonomically it is a dystric xerochrept, and is skeletal and well drained. The soil texture is coarse sandy loam, at least 4 feet deep. The elevation is about 5,000 feet, the slope ranges from 10 to 25 percent, and the aspect is south. Yearly precipitation averages 55 inches with about 70 percent falling as snow. Temperatures range from 20 °F to 95 °F. The growing season is about 120 days.

The experimental design in this study consisted of three treatments each replicated four times in a complete randomized block design. A treatment plot consisted of about one-sixth acre on which were 30 pine seedlings surrounded by at least two rows of buffer (seedlings receiving similar treatment). The treatments were:

- Herbicide sprayed from backpack apparatus in August 1991 with a tankmix of 1.5 percent Accord,[12] 1.0 percent Garlon 4, Bivert adjuvant, and a surfactant to kill bearclover sprouts. Pronone 10G (20 pounds/acre [2 pounds/acre hexazinone]) was applied in November 1991 to limit grasses and forbs.
- Mulches made of woven black polypropylene, 5 feet square, applied around pine seedlings and over bearclover stubs, June 1991. Held in place with nine 8-inch, flat-headed, "u"-shaped metal pins.
- Control (no treatment after site preparation).

In each plot, 20 healthy pine seedlings were selected for study and given a metal tag. Each seedling was measured after the first growing season in 1991 and after the fourth season in 1994 for stem height and diameter. Diameter was recorded at 12 inches above mean groundline. The seedlings were checked periodically for possible injury from animals, insects, and herbicides.

The sampling intensity for measuring other vegetation in the herbicide treatment and the control was five randomly selected subplots in each plot. No subplots were installed in the mulch treatment because each mulch was assumed to completely exclude competing vegetation. Subplots were centered around ponderosa pine seedlings. They were square and contained 1 milacre (0.001 acre). Because very little vegetation was present in 1991, detailed sampling took place only in 1994. Furthermore, only bearclover and cheatgrass were sampled as all other species were too few to analyze.

To test for treatment effects and significant differences among treatments, two-way analysis of variance (mixed model, no interaction)[13] and Bonferroni tests were the analytical tools.[14] We assumed that the block-treatment interaction equalled zero. Unfortunately, three treatments were missing in two plots, resulting in an unbalanced design. Significance in all tests was at $\alpha = 0.05$. To approximate a more normal distribution, the survival data were transformed by arcsin[15] before analysis of variance.

Bearclover and cheatgrass were sampled for density in terms of number of plants per milacre plot and expanded to a per-acre basis. Because new entities of bearclover arise from belowground structures, defining a "plant" was necessary. Excavation and pulling on new stems showed rhizomes to vary widely in depth, length, and origin. Plants from rhizomes consisted of a single stem or a clump of stems. Determining individual plants was impossible. Consequently, single stems and small clumps of stems were counted as one bearclover plant. Determining the density of cheatgrass also was difficult. Plants were so numerous and so close together that it was almost impossible to determine individual plants. We took an inordinate amount of time to do so. Foliar cover (the sum of shadows that would be cast by leaves and stems of each species expressed as a percentage of the land surface)[16] and average dominant height (average of the three tallest stems measured from mean groundline to top of plant) also were recorded for both species. Other species were not measured but noted in a species list.

Data for pines 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 and year separately.

Results

Plant Diversity

Within study plots, almost all species other than bearclover and cheatgrass were scarce and small. The total number of plant species found in the study area from 1991 through 1994 was 19. In 1994, these species consisted of three naturally seeded conifers, two hardwoods, four shrubs, five forbs, one fern, and four grasses. In June 1992, a species of trefoil (*Lotus* spp.) and bull thistle (*Cirsium vulgare* [Savi] Ten.) were present in study plots and abundant outside of them. The tender green seed heads of the bull thistles were being destroyed by the larvae of the painted lady butterfly (*Vanessa cardui*) to the point that virtually no seed was produced. This thistle was scarce in 1993. In summer 1994, only a few plants of trefoil were present and then only in the herbicide plots. One species that grew well among the bearclover plants was a death camas (*Zigadenus exaltatus Eastw.*). Apparently, its large bulb and tendency to grow taller than bearclover gave it a competitive edge.

Bearclover

Burned in early March, bearclover did not sprout above ground until the middle of June. By the end of the growing season in 1994, mean height was 1.2 feet in the control and 0.7 feet in herbicide plots *(table 1*). Only a few young plants were present in the herbicide treatment and most had only one stem. Density of plants in the control was more than 282,000 per acre with cover of 63 percent.

Because rhizome development beneath mulches is unknown, we lifted several mulches in 1994 and dug up the bearclover rhizomes with a shovel. Rhizomes were prolific beneath the mulches and crisscrossed below the soil surface under them. No new roots had developed at rhizome nodes, however. Where aboveground stems had burned, a new white horizontal rhizome was present at the nearest node on some plants. In a few instances this rhizome had resulted in a new plant that had developed in the center slit near the pine

seedling. Beneath the mulches that we lifted were several shoots of bearclover having flattened stems and chlorotic leaves that obviously had been pushing against the mulches. These were beginning to die from heat absorbed by the dark mulch and conducted to them.

Cheatgrass

Although not observed in study plots in 1991, this grass was becoming well established in bare places in 1992. By the end of 1994, cheatgrass was abundant in herbicide-treated plots with a mean density of more than 743,000 plants per acre and foliar cover of 22 percent (*table 1*). More than 130,000 plants per acre were present in the control, but mean foliar cover was only 3 percent.

Table 1—*Growth parameters of bearclover and cheatgrass in herbicide plots and control. Amador Ranger District, Eldorado National Forest, 1994.*

Species and Growth Parameter	Herbicide		Control	
	Mean	SE	Mean	SE
Bearclover				
Density (no./acre)	3,667	3,371	282,000	85,000
Foliar Cover (pct)	1	<1	63	26
Height (ft)	0.7	0.07	1.2	0.2
Cheatgrass				
Density (no./acre)	743,667	299,360	130,300	68,700
Foliar Cover (pct)	22	3	3	<1
Height (ft)	1.0	0.3	1.4	0.6

Ponderosa Pine

Fierce competition from bearclover in the control caused significant mortality of ponderosa pine seedlings by fall 1994. Survival of pines in the herbicide treatment (100 percent) was significantly higher than for pines in the control (73 percent) or surrounded by mulches (77 percent) (*fig. 1*). No damage from insects, browsing, or herbicides was noticed.

Because a majority of ponderosa pine stems were shorter than 12 inches in 1991, mean pine diameter is presented only for 1994. Analysis of variance indicated that pines in the herbicide treatment were significantly larger in diameter (1.8 inches) than counterparts in the control (0.5 inches) or with mulches (0.5 inches) (*fig. 2*). The mean height relationship for ponderosa pine in 1994 was similar to that for diameter. Pines were significantly taller in the herbicide treatment (4.3 feet) than in the control or mulched plots (2.0 feet) (*fig. 3*).

Discussions and Conclusions

Among the many widespread aggressive shrub species that negatively impact young ponderosa pine plantations in the Sierra Nevada of California, bearclover is probably the toughest. Its large and well developed root system and abundant shoot growth enable the species to fully occupy the site both above and below ground. Because of this, most attempts to establish conifer plantations in bearclover have failed. This failure has challenged foresters, and led them to investigate a wide range of site preparation and release techniques. These include manual release (grubbing and chainsawing), mechanical release (discing and bulldozing), dynamiting to create small openings, mulching (sheets of plastic and plywood), prescribed burning (one or more times, various months), and applying herbicides (alone and mixed). Except for the herbicide 2,4,5-T, these

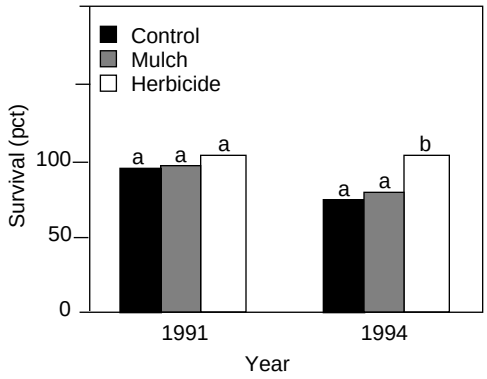

Figure 1—Average ponderosa pine survival by treatment in 1991 and 1994. Standard errors were 2.52 percent in 1991 and 3.84 percent in 1994. For each year, treatment means followed by the same letter do not differ significantly at the 5 percent level.

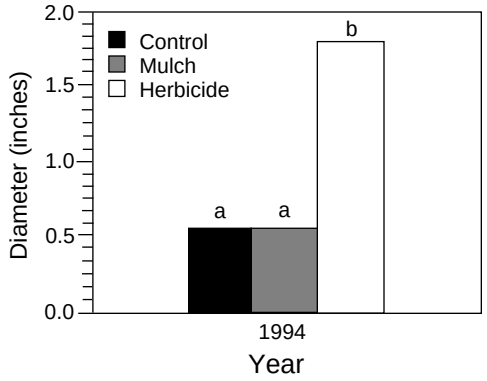

Figure 2—Average ponderosa pine stem diameter at 1 foot above mean groundline in 1994. The standard error was 0.1 inch. Treatment means followed by the same letter do not differ significantly at the 5 percent level.

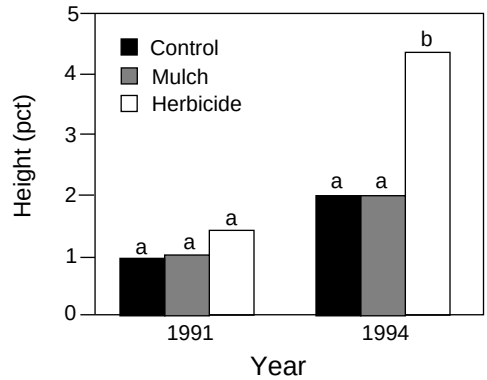

Figure 3—Average ponderosa pine height in 1991 and 1994. Standard errors were 0.08 feet in 1991 and 0.24 feet in 1994. For each year, treatment means followed by the same letter do not differ significantly at the 5 percent level.

trials were inconsistent and ineffective. The plant community that replaced bearclover was often a dense stand of grasses or ferns. These species also proved to be severe competitors to conifer seedlings. After 2,4,5-T became unavailable in the early 1970's, it was not until the mid-1980's that new herbicides were found which killed the entire bearclover plant and not just its crown. But herbicides are not always socially acceptable and new variations of old techniques continue to be tested.

One of these techniques is mulching. Common knowledge suggests that surface dressings such as mulches will not be effective on rhizomatous species. But will they be effective after a high-consumption burn has killed the stems and crowns of the plant? More specifically, will the combination of burning *and* mulching provide the necessary competition-free space to allow ponderosa pine seedling roots to develop enough volume and depth to capture adequate soil moisture to grow well? Results from this study showed that small mulches did not. Furthermore, mulches probably would not be effective, even if they were larger.

Because bearclover rhizomes beneath mulches had no new roots at nodes after four growing seasons, we questioned their source of nourishment. And because the nodes had no roots and hence no water absorption capability, we strived to explain the obviously poor development of the ponderosa pine seedlings in the mulch treatment. The most likely answer consistent with our observations was that roots or rhizomes located much deeper in the soil were extracting soil moisture and denying it to the pines. Nourishment of bearclover probably came from plants outside the mulches as well. Plainly, much more research is needed on the extent and depth of this species' root system, as well as on rhizome stimulation and development. Keying treatment to bearclover phenology needs more work as well.

The constant, perhaps annual, pressure of new bearclover plants against the mulches again demonstrated the need for a tough, heat-absorbing, well anchored mulch.[17]

Because it significantly reduced the bearclover population and delayed the cheatgrass invasion, albeit for only 1 year, the herbicide treatment in this study was effective.

The ability of cheatgrass to compete with bearclover and ponderosa pine seedlings also was investigated. In the control, which was characterized by high bearclover density and foliar cover, cheatgrass density was relatively high (more than 130,000 plants per acre), but foliar cover was low (3 percent). Plants were slightly taller in the control, probably because they were forced to reach for adequate sunlight. Consequently, the competitive strategy (or competitive weakness) of this grass, at least for the first few years, was to maintain a considerable presence in dense bearclover, but not to develop well horizontally.

After a delay of 1 year, cheatgrass colonized the herbicide plots and developed rapidly. By fall 1994, density of this grass was more than 743,000 plants per acre and foliar cover was 22 percent. With an average diameter of 1.8 inches and height of 4.3 feet, the pines were developing well also. Furthermore, visual evidence showed that the length of pine stem between branch whorls was increasing each year, indicating healthy seedlings and continued potential for good growth. Little evidence was present to suggest that cheatgrass was negatively affecting this growth, most likely because the pine roots were able to get to and stay in a zone of adequate soil moisture. By the time the cheatgrass community had developed, the pine roots were below cheatgrass roots and pine crowns were above cheatgrass stems and leaves. Once again, the value of providing conifer seedlings with 1 to 3 years of little or no competition[1] was demonstrated.

Did the high cheatgrass density in herbicide-treated plots directly inhibit bearclover and indirectly enhance pine growth? Density of bearclover was low in the herbicide treatment and all plants were sprouts—none were from seed. Yet

bearclover just outside the plots was flowering profusely and surely must have been producing seed, some of which was disseminated in the study plots. In another study, new bearclover seedlings were found at three locations, over a 2-year period, in both burned and control plots, during March through June.[18] The dense grass may have denied this form of regeneration to bearclover and indirectly aided the growth of the pine seedlings. Another possibility is that no bearclover seed or new seedlings would have been present in herbicide plots in any case.

Before site preparation, the study area was occupied by a few large ponderosa pines and a dense stand of bearclover. It was characterized by limited accessibility and productivity, at least for wood products from trees. After site preparation and planting with ponderosa pine seedlings, the bearclover again became abundant. So did cheatgrass, although its development differed widely between the untreated control and the herbicide-treated plots. In the herbicide plots a future ponderosa pine forest is likely. In the mulched plots and control, the pines are dying and developing poorly. Here, the future plant community will probably consist of pines and abundant bearclover.

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