Response of Planted Ponderosa Pine Seedlings to Weed Control by Herbicide in Western Montana

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ABSTRACT: *The effects of competing herbaceous vegetation on the growth of ponderosa pine seedlings with and without the herbicide Pronone were characterized in this 1987–1990 study. Study areas were established in 36 plantations across western Montana on Champion International Corporation's timberland (currently owned by Plum Creek Timber Company). The study sites were divided into three precipitation classes: low, medium, and high. Mean percent stem volume growth was calculated for 3 yr by precipitation class. Split-plot analyses of variance for precipitation class, treatment, and interaction were conducted across sites between treated and untreated seedlings to test for significant (a = 0.05) differences in growth. A two-dimensional plot of precipitation class by treated versus untreated trees was constructed to show growth rate trends. After 3 growing seasons, the treated seedlings showed significantly higher stem volume growth than their untreated counterparts regardless of precipitation class. The difference between treated and untreated seedlings was statistically significant. West. J. Appl. For. 14(1):48–52.*

Conifer release has become one of the popular tools that aid forest managers in increasing forest productivity. Miller (1986a) stated that conifer release treatment is the selective control of noncrop vegetation competing with crop trees or seedlings in plantations or naturally generated stands for light, nutrients, and soil moisture. Regarding the Inland Northwest, he contended that the most important limiting factor in conifer regeneration is competition with noncrop vegetation. The objectives of conifer release treatments include: control of unwanted vegetation before mortality of the seedlings or losses in growth of the seedlings have occurred (Peterson 1986, Blake and Crooker 1986, McDonald and Fiddler 1995); treating the sites before noncrop vegetation becomes dominant (Miller 1986a, McDonald and Fiddler 1989, McDonald et al. 1996); and providing nutrients and moisture to crop trees (Lotan 1986, McDonald and Fiddler 1995, Roth and Newton 1996).

There are two principal methods the silviculturist can adopt to control competing vegetation: chemical and mechanical (Mahoney 1986, McDonald et al. 1996, Fiddler and McDonald 1997). Mechanical methods have been the standard in the Inland Northwest for many years (Mahoney 1986).

Chemical methods, however, have advantages over other treatment methods. Chemical methods conserve soil moisture; prevent loss of topsoil; can be applied regardless of slope steepness; result in fewer operator injuries; allow seedlings to be planted into decomposing rather than live sod; can provide the best result with the least disturbance to the environment, tree survival, and growth; are the most economical when properly applied; do not compact the soil; do not immobilize nutrients by decomposing plant parts; and do not encourage germination of noncrop seeds (Mahoney 1986, and McDonald et al. 1994a) Chemical methods have the following disadvantages: they are not effective on all species of noncrop vegetation, and their use is constrained by environmental and social concerns (Boyd 1986a, Erickson and Morris III 1986, McDonald et al. 1994b)

Although release treatments enhance seedling survival rates, release treatments are more effective in years of moisture stress. Furthermore, effectiveness of chemical methods is dependent on weather (moisture stress), species, age of competing noncrop vegetation in question, soils, and type of treatment used (Boyd 1986b, McDonald et al. 1994a). For optimum treatment effects on noncrop vegetation, time of herbicide application is of primary importance (Miller 1986b, Wagner and Rogozynski 1994).

The objective of this study is to characterize the growth of ponderosa pine seedlings when competing herbaceous vegetation is killed with the herbicide Pronone 10G (Hexazinone). Of particular interest is the effect of release treatments in moisture-limiting environments on various site and tree-growing conditions.

Study Area and Methods

This study began in the summer of 1987. Thirty-six plantations were located in western Montana on Champion International Corporation fee lands (Figure 1) (currently owned by Plum Creek Timber Company) and ranged in size

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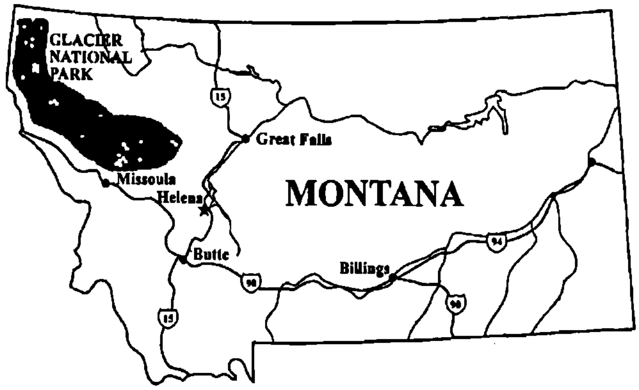

Figure 1. Study area (in shading) in western Montana. Each location may have more than one plantation.

from 14 to 36 ac. Reforestation reports and plantation information from 1980 to 1986 for all Champion lands were accessed. From these reports, those plantations that had been clearcut and planted with mainly ponderosa pine (*Pinus ponderosa*), with homogeneous aspect, slope, and geomorphological characteristics within the area, were selected. Reforestation areas were separated into three elevation classes (low = 2000–3400 ft; medium = 3500–4900 ft; high = 5000–6600 ft). Each elevation group was divided into three precipitation classes (low = 15–29 in.; medium = 30–44 in.; high > 45 in.). Finally, the plantations were grouped into 3 age classes (low = 3–4 yr; medium = 5–6 yr; high = 7–10 yr).

The plantations were selected with the aim of filling the cells of a 3 × 3 × 3 sampling matrix of precipitation, elevation, and age—each divided into low, medium, and high levels as described above. I was unable to fill all the cells (see Table 1), however, partly because of the silvical characteristics of ponderosa pine and because of the lack of plantations that could fill certain cells.

Ponderosa pine seedlings were measured in the summers of 1987, 1989, and 1990 for height, live crown length, crown width, and diameter at 0.5 ft above the mean groundline. The percent cover of herbaceous vegetation (grasses, sedges, forbs, and shrubs) was estimated at the same time by summing [vertical shadows that were cast by grass blades, leaves, and stems of individual species expressed as a percentage of ground surface (Daubenmire 1968)]. The radius of the area that was measured around each seedling/sapling for competing vegetation was between 3 and 5 ft, depending on plantation age and tree size.

At each plantation, the sampling point center was located at random near the middle of the plantation. Sampling within a plantation was carried out in a spiral with ever-increasing radius from the sampling point center. Sampling continued until the cells of a 3 × 3 sampling matrix were filled. The sampling matrix consisted of crown ratio (ratio of crown length to tree height) and vegetation cover, each divided into low, medium, and high levels, with at least two replications/cell. For crown ratio, high > 0.75, medium = 0.75–0.5, and low < 0.5. For competing herbaceous vegetation cover, high > 55%, medium = 55%–35%, and low < 35%.

Grasses, the dominant competing herbaceous vegetation in the plantations, included bluebunch wheatgrass (*Agropyron spicatum*), rough fescue (*Festuca scabrella*), Idaho fescue (*Festuca idahoensis*), pinegrass (*Calamagrostis rubescense*), elk sedge (*Carex geyerii*), and cheatgrass (*Bromus tectorum*). However, the following forb and shrub species—beargrass (*Xerophyllum tenax*), ninebark (*Physocarpus malvaceus*), creeping holly grape (*Berberis repens*), snowberry (*Symphoricarpos albus*), twinflower (*Linnaea borealis*), kinnickinnick (*Arctostaphylos uva-ursi*), white spirea (*Spirea betulafolia*), menziesia (*Menziesia ferruginea*), thinleaf huckleberry (*Vaccinium globulare*), and ceanothus (*Ceanothus velutinus*)—were sparsely scattered across some of the plantations.

The granular form of the herbicide Pronone (2 lb/ac active ingredient) was used for release treatment because it is not damaging to ponderosa pine, and it readily penetrates through the grasses, forbs, sedges, and shrubs to the ground. Using the response surface methodology of Box and Draper (1987), the herbicide was applied by spot application at each plot as a release treatment in the fall of 1987. Their technique, which is systematic, samples the corner and center cells of the 3 × 3 sampling

Table 1. The matrix of plantation selection showing number of plantations/cell (and height range in ft). For elevation classes (low = 2000–3400 ft; medium = 3500–4900 ft; high = 5000–6600 ft); for precipitation classes (low = 15–29 in.; medium = 30–44 in.; high > 45 in.); and for age classes (low = 3–4 yr; medium = 5–6 yr; high = 7–10 yr).

	Precipitation					
	High		Medium		Low	
	[No./cell range (ft)]					
Low Elevation						
Low age	0		3	(0.8–4.3)	2	(0.8–2.1)
Medium age	1	(2.4–6.3)	1	(2.0–5.7)	2	(2.1–5.5)
High age	0		2	(4.1–11.4)	2	(3.3–7.8)
Medium Elevation						
Low age	1	(2.0–5.2)	1	(0.8–2.5)	0	
Medium age	0		2	(2.3–5.0)	3	(1.5–5.1)
High age	0		0		5	(1.5–6.4)
High Elevation						
Low age	0		1	(1.0–2.4)	3	(0.8–4.2)
Medium age	0		2	(1.5–5.6)	1	(1.2–2.8)
High age	0		1	(2.5–6.2)	3	(1.3–5.8)

matrix of crown ratio and competing herbaceous vegetation cover. Only one replication in each case was needed. Seedling growth was monitored for 3 yr—1988 to 1990. Percent stem volume growth was used to measure the difference in growth response between the treated and the untreated ponderosa pine seedlings. Stem volume (using the formula for a cone) and percent stem volume growth were calculated with these equations:

$$\text{stem volume} = \pi * D^2 * HT / 12$$

$$\text{percent volume growth (PVG)} = \frac{FSV - ISV}{ISV} * 100$$

where D is the diameter in inches at 0.5 ft above the mean ground line, HT is the total seedling height, FSV is the final stem volume (1990 stem volume), and ISV is the initial stem volume (1987 stem volume).

Statistical Analysis

Analyses of variance (ANOVA) including age, available water capacity (W), precipitation (P), and elevation were carried out but were found to be nonsignificant with the exception of age (SPSS 1997). Age was not used in the analysis, however, because age and competing vegetation were confounded. Hence a split-plot ANOVA is presented that contains only precipitation classes and treatment. A two-dimensional bar chart of the 3-yr mean percent stem volume growth for treated and untreated seedlings by precipitation class was constructed (Figure 2). Split-plot analyses of variance for precipitation class, treatment, and their interaction were conducted to test for a significant ($\alpha = 0.05$) difference in mean percent stem volume growth across plantations between treated and untreated trees.

Percent stem volume growth response for treated and untreated trees was analyzed by a split-plot ANOVA (Mead 1988) with the following model:

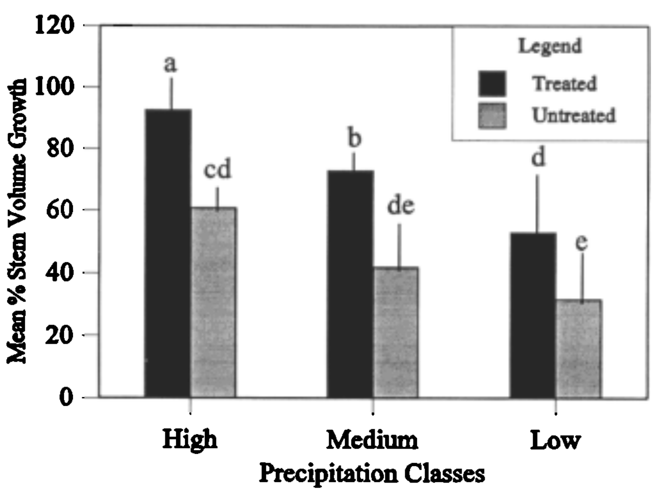

Figure 2. Three year mean percent stem volume growth for treated and untreated trees over three precipitation classes (class 1 = high; class 2 = medium; class 3 = low). Vertical lines above bars represent one standard error. Bars with the same letter are not significantly different at the 95% confidence level using Bonferroni's least significant difference (LSD) (Millken and Johnson 1984).

$$Y_{ij_ik} = \mu + P_i + S(P)_{ij_i} + T_k + T * P_{ik} + T * S(P)_{kij_i} + \epsilon_{ij_ik}$$

where

μ = the general level of average percent stem volume growth;

$P_i = 1,2,3$ = precipitation class number;

$S_{j_i} = 1,...$ = plantation in cell i

$T_k = 1,2$ = treatment number: 1 = treated, 2 = control;

ϵ_{ij_ik} = error term; and

$S(P)$ and $T*S(P)$ are random factors.

Results

During the study period, eight seedlings died at two sites located in the Gold Creek area near Missoula. The seedlings died in the blizzard of January 31—February 1, 1989, which had a wind chill factor of –79°F (temperature data were obtained from the monthly climatological data published by the National Weather Service, NOAA). This compares well with the findings of Sutton (1984) for Ontario, where the removal of overtopping shrubs resulted in greater frost damage to understory spruce.

The mean percent volume growth response by precipitation classes for treated and untreated seedlings is depicted as grouped bar charts in Figure 2. On all sites, after 3 growing seasons, the treated seedlings showed a significantly higher percent volume growth than their untreated counterparts

Table 2 displays split-plot design analyses of variance of percent stem volume growth for treatment and precipitation class. Treatment was statistically significant at $\alpha = 0.05$; precipitation class was not. The interaction between treatment and precipitation class was not statistically significant, indicating that the difference in mean stem volume growth response after 3 growing seasons between the treated and untreated seedlings was constant across precipitation classes

Table 3 shows the average percent cover of grasses, forbs, sedges, and shrubs for treated and untreated ponderosa pine seedlings by precipitation classes, 1987–1990. The plant community at the end of the 3 growing seasons in treated areas consisted of only grasses and forb species and ponderosa pine. Shrub seedlings were excluded even on sites where shrubs were sparsely scattered before treatment.

Discussion and Conclusions

After logging and before planting, the sites were prepared either with broadcast or pile burning. During herbicide application, the older sites and some of the younger ones were already experiencing a high level of competition from herbaceous vegetation. On the other hand, some of the younger sites displayed medium to low competition from herbaceous vegetation. As a result, age and competing vegetation were

Table 2 Two-way analysis of variance of percent stem volume growth between precipitation classes and treatment (treat) factors.

Source	Analysis of variance				
	Sum of squares	*Df*	Mean square	*F* ratio	*P*
Class	0.106292*E* + 09	2	0.531461*E* + 08	1.258	0.297
Site (class)	0.139426*E* + 10	33	0.422502*E* + 08		
Treat	0.194979*E* + 08	1	0.194979*E* + 08	8.449	0.004
Treat * class	29,946,606.430	2	1,497,303.215	0.649	0.523
Error	0.106616*E* + 10	462	2,307,716.153		
Total	0.261615*E* + 10	501			

confounded. The average percent cover across the 3 site classes before treatment ranged from 52% to 73% (Table 3). During the course of the study, as indicated in Table 3, the competition on all of the untreated sites increased. However insignificant, the competition on all of the treated sites increased gradually as well. The average percent cover across the 3 precipitation classes after 3 yr (1990) ranged from 89 to 91% for untreated seedlings and from 1 to 2% for treated seedlings. Thus, Table 3 indicates that the use of herbicides is applicable for many plant communities because of their effectiveness in killing both sprouting and nonsprouting plants. This finding supports other work, such as that by McDonald and Fiddler (1993).

On all plantations, stem volume growth of ponderosa pine was greater in the treated seedlings than in their untreated counterparts because of greater availability of moisture and nutrient (McDonald and Fiddler 1995, Roth and Newton 1996). After the 3 growing seasons, treated trees on precipitation classes 1, 2, and 3 were growing at the rate of 93, 73, and 53% on average/annum (Figure 2). On the other hand, their untreated counterparts were growing at the rate of 61, 42, and 32%, respectively, per annum. These differences in volume growth due to treatment were statistically significant at $\alpha = 0.05$.

After the first growing season, the effects of treatment were not statistically significant in the high precipitation class After the second and third growing seasons, however, the growth rate of the treated trees was much higher than that of the untreated trees (Figure 2). The differences were statistically significant (Table 2). Based on research results by McDonald and Oliver (1984) and McDonald et al. (1994a), I expect this growth difference to continue for many years.

Growth and survival of seedlings in young plantations can be limited by soil moisture availability affected by competing noncrop vegetation (McDonald and Fiddler 1995, Roth and Newton 1996). In this study, however, the effect of precipitation classes was not statistically significant because only two plantations occurred in the cells of high precipitation class (Table 1). Consequently, there were not enough data from that precipitation class to truly detect the effects of precipitation classes in the output of the split-plot analysis of variance.

Meanwhile, the depletion of soil moisture experienced by newly established seedlings in pine plantations is closely related to the surface cover of herbaceous vegetation competing with the seedlings (Table 3 and Figure 2). With increasing stress caused by competing herbaceous vegetation, stemwood growth is reduced but not sufficiently to cause mortality. This results in the seedlings allocating photosynthate from stemwood production to root production in order to access water stored in deeper soil layers (Peterson 1986).

From the foregoing statistical results and information presented in Tables 2 and 3 and in Figure 2, the following conclusions, applicable to a large area in northwest and west-central Montana, can be made:

1. Regardless of precipitation class, after 3 growing seasons, the treated seedlings showed a significantly higher stem volume growth than their untreated counterparts.

2. The difference in mean percent volume growth by precipitation class between treated and untreated seedlings was not statistically significant at $\alpha = 0.05$.

3. The interaction between treatment and precipitation class is not statistically significant and thus indicates that the difference in mean percent stem volume growth response after 3 growing seasons between treated and untreated seedlings is constant across precipitation classes. Nevertheless, Figure 2 shows that on poor sites, the percent of volume loss from competing vegetation is greater than the loss on good sites, but the absolute loss seems to be less.

4. Competing herbaceous vegetation was the most important factor affecting seedling survival and growth because treatment was the most statistically significant main effect (Table 2).

Table 3. Average percent cover of grasses, forbs, sedges, and shrubs for treated and untreated ponderosa pine seedlings by precipitation classes (class 1 = high; class 2 = medium; class 3 = low), 1987–1990.

Year	High		Medium		Low	
	Treated	Untreated	Treated	Untreated	Treated	Untreated
1987	72.6	71.1	67.5	62.7	54.0	51.7
1989	0.9	80.2	1.3	80.5	0.0	68.9
1990	1.8	91.0	1.8	85.5	1.1	89.4

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