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Planted conifer and surface vegetation responses to herbaceous vegetation control in western Montana

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Planted Conifer and Surface Vegetation Responses to Herbaceous Vegetation Control in Western Montana

by

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Planted Conifer and Surface Vegetation Responses to Herbaceous Vegetation Control in Western Montana (pp. 53)

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Abstract

In western Montana, grass/sedge and other herbaceous plants compete with planted conifer seedlings for site resources. Competition leads to decreased survival and growth rates, prolonging forest stand establishment. To counter the effects of herbaceous vegetation, mechanical and/or chemical herbaceous vegetation control (HVC) treatments may be applied as part of site preparation during or soon after planting. If successful, initial increases in seedling survival and growth are expected. However, long term trends in seedling survival and growth as well as other above-ground vegetation responses to treatments are not well documented. The objective of this study was to summarize the long-term development of planted conifer seedlings and other vegetation in response to HVC treatments during site preparation in western Montana.

Three HVC trials, 1981 (two sites), 1983 (two sites), and 1985 (four sites), were re-measured in the fall of 1996 and summer of 1997. HVC treatments consisted of mechanical handscalping prior to planting (1981) and one-time applications of herbicides within (+/-) one year of planting (all trials). Re-measurement of these trials yielded up to 16 years of planted conifer and other vegetation responses to the HVC treatments. Analyses included ANOVA F-tests and Duncan's Multiple Range Tests to compare average plot survival, plot volume, tree DBH, tree height growth, tree volume, grass/sedge cover and total cover percentages across the various HVC treatments at the 0.05 significance level. Mean annual height growth trends were displayed graphically.

Handscalping did not significantly affect the long-term development of ponderosa pine seedlings and other vegetation. Herbicide HVC treatments increased individual tree growth and/or survival which was manifested in plot volume calculations. Lodgepole pine plot volumes increased up to 532% (1983 trial) and 1,727% (1985 trial) for 2-0 bare root lodgepole pine stock after 16 years. Lodgepole pine 1-0 container stock plot volume increased 822% (1983 trial) and 1,842% (1985 trial). Western larch plot volume increased 2,478% (1985 trial). Recent (< five years) annual height curves are parallel (1981 trial) or continuing to diverge (1983 and 1985 trials) from the check plots. Decreased herbaceous and total vegetation percent cover was found in chemical site preparation treatment plots. These results indicate that herbicide HVC increases the long-term growth of planted conifers in western Montana.

Keywords: competition, mechanical and chemical site preparation, herbaceous vegetation control (HVC), conifer seedling, ANOVA, Montana.

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"A teacher enlarges people in all sorts of ways besides just his subject matter"

~Wallace Stegner, Crossing to Safety

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Introduction

Successful forest stand establishment is dependent upon the degree of competition between tree seedlings and other above-ground vegetation. Competition for site resources will be more vigorous with increased surface vegetation cover. As a consequence, tree seedling survival and growth may decline, resulting in spotty tree regeneration and a lengthening of forest stand establishment. To counter these effects, mechanical and herbicide site preparation methods aimed at controlling competing vegetation may be employed prior to or soon after planting. Both methods attempt to kill the above and/or below ground plant parts of the competing vegetation, thus freeing up site resources for tree seedlings. If successful, tree seedling survival and growth is expected to increase, ensuring prompt stand establishment.

In western Montana, ponderosa pine (*Pinus ponderosa* Dougl. Ex Laws.) and Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco) habitat types along with grand fir (*Abies grandis* (Dougl. Ex D. Don) Lindl.) habitat types in the valley bottoms are common at low elevations (Pfister et al. 1977). Herbaceous vegetation is the prominent competitor with seedlings during stand establishment in these habitat types. Consequently, vegetation control treatments are usually directed towards limiting the amount of herbaceous vegetation. Common herbaceous vegetation control (HVC) treatments in western Montana include hand scalping during planting and occasionally, one-time spot applications of moderate to long persistent herbicides following planting.

When HVC is successful, the questions at hand are: 1) what are the initial effects on seedling survival and growth; 2) how long will the effects on tree seedlings last; and 3) how will the treatments affect long term surface vegetation development? Embedded within these questions are factors affecting the efficacy and longevity of the HVC treatments and factors affecting seedling quality. Examples of these factors include herbicide types, rates, and season of application, along with seedling stock type, size, and planting season in relation to the HVC treatment.

The author of this thesis addresses these questions by reporting the long term results of three HVC trials established by Champion International Corporation (CIC) from 1981 to 1985 on herbaceous plant dominated sites in western Montana. These trials are named after the year they were enacted, e.g. the 1981 trial began in 1981, the 1983 trial in 1983, and the 1985 trial in 1985. HVC treatments included one-time applications of moderate to long persistent herbicides and handscalping within (+/-) one year of the planting of three conifer species: ponderosa pine, lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.), and western larch (*Larix occidentalis* Nutt.).

Objective

From these trials, the development of planted ponderosa pine, lodgepole pine and western larch seedlings in response to the various HVC treatments is described for up to 16 years. Other above-ground vegetation development is also described. In doing so, I compare the average plot survival, plot volume, tree dbh, tree height growth, tree volume, grass/sedge cover and total vegetation cover across the various HVC treatments for each trial.

Hypotheses

Below are two general hypotheses that were used to guide the analyses for tree responses (hypothesis 1) and vegetation responses (hypothesis 2) to the HVC treatments.

1) H_o: There are no population differences in average plot survival, plot volume, tree DBH, tree height, tree periodic height growth and tree volume due to the trial-defined HVC treatments, seedling stock types, or planting dates at the time of trial re-measurement.

   H_1: Not H_o.

2) H_o: There are no population differences in average grass/sedge cover and total above-ground cover due to the trial-defined HVC treatments at the time of trial re-measurement.

   H_1: Not H_o.

Literature Review

Conifer seedlings compete with a variety of vegetation including grass-like plants, forbs, shrubs, and other woody plants including hardwoods. As competition from these plants increase, water and nutrient availability decreases (Carter et al. 1984). Research results of 260 vegetation control studies on the growth and survival of 39 forest tree species covering most regions of the United States are contained in Stewart et al. (1984). The majority of results indicate that by controlling competing vegetation, the availability of site resources increase, and forest trees increase their growth and survival rates.

Conversely, the availability of site resources for seedlings decreases with increasing competing vegetation cover. As such, a decrease in seedling survival and growth may occur. Petersen (1986) related this phenomenon to a modified application of the Reciprocal Yield Law (Spitters 1983), showing a sigmoidal relationship between tree growth and weed density. With increases in the leaf area of grasses, Petersen (1986) observed a dramatic drop in ponderosa pine stem volume growth.

As mentioned earlier, herbaceous vegetation dominates dry sites during stand establishment in the Inland Empire (eastern Washington, eastern Oregon, Idaho, and western Montana). Crouch (1986) reported grass to be the major competitor with ponderosa pine seedlings for the first 18 years of plantation growth in south-central Oregon. However, competing vegetation composition changes as stands develop on treated plots after HVC. Crouch (1986) reported a change from grass to shrub cover on treated plots over 18 years. Stein (1997) reported a similar outcome for herbaceous plants on good sites along the Oregon coast. Grass cover began decreasing after three years and salmonberry cover after five years following control treatments. Woody cover increased from 6.4% to 69.5% over the 10-year period. As woody cover increases, less light is made available and herbaceous cover decreases.

Southeast United States

The intensive tree farming found in the southeast United States lends itself to the use of vegetation control methods. Appropriately, a considerable amount of research has been conducted on HVC treatments. Most of the research in the southeast has focused on southern pine plantations where seedlings compete with a combination of woody and herbaceous plants for site resources. Tree species of concern include loblolly pine (*Pinus taeda* L.), longleaf pine (*Pinus palustris* Mill.), shortleaf pine (*Pinus echinata* Mill.) and slash pine (*Pinus elliottii* Engelm. var. *elliottii*). Control of herbaceous vegetation is primarily conducted through herbicide use while woody vegetation is controlled through herbicides and manual methods.

Miller et al. (1991), Zutter et al. (1995), and Zutter and Miller (1998) reported five, eight, and eleven-year responses, respectively, of competing vegetation and loblolly pine to woody and/or herbaceous vegetation control treatments on plots throughout the southeast as part of the Competition Omission Monitoring Project. Following three years of vegetation control, volume growth increased by 171% in herbaceous vegetation control plots and 67% in woody vegetation control plots after five years (Miller et al. 1991). However, with the long term analysis by Zutter and Miller (1998), height gains from the herbaceous vegetation control plots had been decreasing since age seven. This coincided with dramatic decreases in herbaceous plant cover starting at age six with dramatic increases in woody plant cover after year eight for all treated and check plots. Pine density in trees per acre (TPA), a surrogate for survival, was not affected by the plant control treatments throughout the 11 years.

Other studies show increases in individual tree growth following herbaceous vegetation control for loblolly pine up to five years after planting (Nelson et al. 1981, Michael 1985, Tiarks and Haywood 1986, Zutter et al. 1986, Yeiser and Williams 1996) and shortleaf pine one year after planting (Yeiser and Barnett 1991). Increases in slash pine seedling growth to herbaceous vegetation control in Florida was also evident five years after planting, but was overshadowed by larger increases in growth due to shrub control (Lauer and Glover 1995). Due to the short time span of these trials, it is uncertain whether the initial growth gains would be maintained.

Established stands of southern pines also increase growth following vegetation control if substantial herbaceous vegetation exists before treatment. Two to seven-year old stands of loblolly, longleaf, and slash pine increased growth one year after herbaceous vegetation control (Creighton et al. 1987). Eight years following complete vegetation control applied to five to sixteen-year old stands of loblolly pine, growth was positively correlated with the amount of vegetation controlled, mostly woody vegetation (Fortson et al. 1996).

There is no definitive pattern in the survival of southern pines after herbaceous vegetation control. Results from Michael (1985), Zutter et al. (1986), Cain (1991), and Lauer and Glover (1995) showed no impact on survival . Other results by Tiarks and Haywood (1986), Creighton et al. (1987), and Yeiser and Williams (1996) showed increases in survival. Negative effects on survival were not apparent.

Western United States

Competing vegetation composition changes with the prevailing precipitation patterns in the western United States. In the southwest and in the Inland Empire where drier sites prevail, competition for tree seedlings comes mainly from grass and herbaceous vegetation. On moist sites, shrubs become the more dominant resource competitor. In the coastal ranges where moist sites prevail, shrubs at times in combination with herbaceous plants (Barrett 1970) are the major competitors with conifer seedlings. Hardwood competition also becomes more intense.

On dry sites when moisture is limited, herbaceous vegetation has been shown to decrease ponderosa pine survival and growth (Larson and Schubert 1969, Crouch 1979 1985, Boyd 1985). Larson and Schubert (1969) found an 11-fold increase in ponderosa pine dry weights with grass control treatments after two years. Survival was dependent on water availability for controlled areas. Increased survival occurred in un-watered areas with grass control, while no increase in survival was evident in well-watered areas. Boyd (1985) reported similar results in Montana with increased conifer seedling survival following herbaceous vegetation control during dry years. Positive effects on survival were absent during wet years. Individual tree growth increased with herbaceous vegetation control. Crouch (1979, 1986) found a 55% increase in ponderosa pine survival and a 32% increase in height growth 10 years after herbaceous vegetation control.

Mechanical and/or herbicide control measures were utilized in the above studies. Both methods increased seedling survival and growth when the control measure worked. Sloan and Ryker (1986) reported a need for at least 4 feet x 4 feet sized handscalps centered on seedlings for enough control to increase Douglas-fir, ponderosa pine and lodgepole pine survival and growth in central Idaho. Properly timed broadcast sprays of herbicide provide more control over competing vegetation than the former and spot sprays.

HVC release treatments in western Montana have also been shown to increase the growth of established conifer seedlings. Uzoh (1999) reported three-year increases in stem volume of established ponderosa pine seedlings between three to ten years of age. Herbaceous vegetation was the dominant competitor in this study.

Previous Results of Champion International Corporation Trials

Periodic re-measurement of the three CIC trials reported in this thesis occurred numerous times during the 1980's and again in 1990. Summaries of these re-measurements were published in Champion International research notes by Petersen (1982), McLeod and Mandzak (1990) and Thamarus and Milner (1989). A brief summary of these results is presented below.

All trials reported good control of grass with hexazinone herbicides (Velpar L and Pronone) and the Oust herbicide for one to two years after HVC application (Petersen 1982, McLeod and Mandzak 1990, and Thamarus and Milner 1989). Re-invasion of forbs was seen with the Oust treatments within two years (Thamarus and Milner 1989). Re-invasion by grass/sedges in higher rates of Velpar L was less after seven years than in the lower rates in the 1983 trial (McLeod and Mandzak 1990). There was no report on the control success of the handscalping treatment.

First year seedling survival increased for Velpar L herbicide treated plots and decreased for the Roundup treated plots in the 1981 trial (Petersen 1982). Herbicide toxicity to seedlings combined with lack of timely vegetation control in the Roundup treatments decreased survival. Roundup herbicide was applied at the time of maximum vegetation expression, which in western Montana is of little help in conserving soil moisture for seedling survival (Petersen 1982). As a result, vegetation cover was not severely impacted in Roundup treatments during the first year. The Velpar L treated plots showed increased basal diameter and plantation growth index (mean basal diameter^2 * mean height * mean survival = PGI). PGI increases were a factor of increased survival and basal diameter. The handscalping treatment increased survival for shaded seedlings but not growth.

Six and seven year results of the 1983 trial indicated increased lodgepole pine growth with higher Velpar L herbicide rates as well as with the spring applications (McLeod and

Mandzak 1990). Survival in treated plots increased at Gold Creek and decreased at Boyd Mountain presumably due to the dominant type of vegetation at these sites (McLeod and Mandzak 1990). While grass/sedges were controlled at both locations, shrubs dominated the Boyd Mountain site and grass/sedges dominated the Gold Creek site. The high shrub cover at Boyd Mountain probably decreased survival. Tree growth (basal diameter, height and tree volume) for treated plots at both sites were still increasing over the check plots after six and seven years.

Second year results in the 1985 trial indicated increased lodgepole pine and western larch survival and growth with successful vegetation control (Thamarus and Milner 1989). Large increases in lodgepole pine survival were found at the Bear Creek and Lost Prairie sites while survival at Gold Creek and Smiley Creek sites was not dramatically improved. Large increases in western larch survival occurred at Smiley Creek, Bear Creek and Lost Prairie. Lodgepole pine volume increased at all sites with increased herbicide rate and efficacy two years after treatment. Increases were between 27% and 1270% greater than the check plots. Western larch volume also increased with vegetation control at all locations, up to 4798% greater in treated plots.

Summary

Herbaceous plants often dominate sites during stand establishment. However, in the southeast and pacific northwest of the United States, herbaceous vegetation begins to decrease three to eight years after plantation establishment (Stein 1997, Zutter and Miller 1998). This coincides with a greater amount woody cover as the stand ages. Prior to decreases in herbaceous plant cover, controlling herbaceous vegetation was shown to increase planted conifer growth. Afterwards, herbaceous vegetation control may not benefit tree growth and is based on the presence (Creighton et al. 1987, Fortson et al. 1996) or absence (Zutter and Miller 1998) of herbaceous vegetation.

In the Inland Northwest, herbaceous plants, specifically grasses and sedges, may dominate the surface vegetation for a considerable period of time during the life of a stand. If controlled during site preparation or during a release operation, planted seedlings will initially increase growth. Survival may also increase, as long as seedlings are not harmed by the vegetative control method and water is in short supply. It is unclear how long herbaceous vegetation control in the Inland Empire will benefit seedling growth.

Methods

CIC established three herbaceous vegetation control trials on sites located in western Montana in 1981, 1983, and 1985 (Table 1). Each trial consisted of HVC treatments applied within rectangular plots containing two to six rows of seedlings. HVC treatments included spot handscalping and spot herbicide applications centered on the seedlings as well as broadcast herbicide applications to entire plots within one year (+/-) of planting. HVC treatments are defined by trial and in some instances by site (Table 2). The number of seedlings per row varied by trial. Treatments were replicated on-site as well as across sites under various factorial designs (Tables 3-5). The latest re-measurement of these trials occurred in 1996/1997. A summary of the latest re-measurement is presented in this thesis yielding tree and surface vegetation response data for up to 16 years. Analyses were performed on plot, tree, and surface vegetation variables.

Table 1. Site descriptions for 1981, 1983, and 1985 trials.

Trial	Site	Elevation (feet)	Aspect	Slope (%)	Habitat Type
1981*	Cow Creek	4800	SW	20	PSME/CARU
	Murr Creek	4300	S	40	PSME/CARU
1983†	Gold Creek	4100	N-NE	2	PSME/VACA
	Boyd Mountain	5300	NW	40	PSME/VAGL
1985‡	Gold Creek	4100	-----	level	PSME/VACA
	Bear Creek	3050	-----	level	ABGR/LIBO
	Lost Prairie	3600	S-SW	8	PSME/VACA
	Smiley Creek	4300	NW	12	ABGR/LIBO

* - Petersen (1982)

† - McLeod and Mandzak (1990)

‡ - Thamarus and Milner (1989)

Trial Descriptions

1981 Trial

Established in 1981, this trial sought to determine the effects of handscalping and herbicide HVC and shading on the survival and growth of ponderosa pine seedlings on four herbaceous plant dominated sites (Petersen 1982). Petersen (1982) and on-site verification by the author provided the trial information below. The Murr Creek and Cow Creek sites were re-measured in 1997, results of which are presented in this thesis. HVC treatments included two herbicides with two methods of application, and handscalping. Herbicide treatments included Velpar L at a rate of two pounds active ingredient (a.i.) per acre and Roundup at a 1.5 percent solution rate. The active ingredient in Velpar L is a liquid form of hexazinone while Roundup is a liquid form of glyphosate. Herbicide treatments were applied as broadcast treatments (entire plot) and spot treatments (four feet by four feet square centered on the seedling). Handscalping consisted of mechanically removing all vegetation on a four feet by four feet square centered on the seedling. Shade cards were used to test seedling response to shading. A shade card was an eight by twelve inch piece of cardboard attached to a wooden stake placed on the southern side of the planted seedling.

Five blocks provided replication at each site, of which four were re-measured during 1997. Two shade card treatment zones were randomly assigned within each block. Within the shade card treatment zones, 16 feet by 96 feet check and HVC plots were assigned at random. Cow Creek treatment plots included broadcast Velpar L, spot Velpar L, broadcast Roundup, spot Roundup, handscalp, and a check plot. The handscalp treatment was not applied at Murr Creek. Within each treatment plot, 30 ponderosa pine seedlings of 2-0 bare root stock were planted along two rows on a six feet by six feet spacing during the spring of 1981. A complete trial description may be found in Peterson (1982).

1983 Trial

The 1983 trial was established as a continuation of the 1981 trial (McLeod and Mandzak 1990). The purpose of this trial was to determine the effects of herbicide HVC treatments on the survival and growth of lodgepole pine seedlings on three herbaceous-plant dominated sites. McLeod and Mandzak (1990) and on-site verification by the author provided the following trial information. The Gold Creek and Boyd Mountain sites were re-measured in the summer of 1997.

Treatments were replicated across three blocks at each site. Within blocks, there were nine herbicide treatment plots and one check plot assigned at random; however, only four

Table 2. Abbreviations of the various HVC treatments and HVC-planting date treatment combinations for all trials.

Trial	Abbreviation	Definition
1981	BR	broadcast Roundup, spring 1981
	BV	broadcast Velpar L., spring 1981
	HS	hand scalp, spring 1981
	SR	spot Roundup, spring 1981
	SV	spot Velpar L., spring 1981
	C	check
1983	V2S-A	Velpar L. applied at a rate of 2 pounds/acre in the spring of 1983 after planting
	V2S-B	Velpar L. applied at a rate of 2 pounds/acre in the spring of 1983 before planting
	V2F-B	Velpar L. applied at a rate of 2 pounds/acre in the fall of 1983 before planting
	V4S-A	Velpar L. applied at a rate of 4 pounds/acre in the spring of 1983 after planting
	V4S-B	Velpar L. applied at a rate of 4 pounds/acre in the spring of 1983 before planting
	V4F-B	Velpar L. applied at a rate of 4 pounds/acre in the fall of 1983 before planting
	C	check
1985	P2F-F85	Pronone applied at a rate of 2 pounds/acre in the fall of 1985, planting in fall of 1985
	P2F-S86	Pronone applied at a rate of 2 pounds/acre in the fall of 1985, planting in spring of 1986
	P2S-S86	Pronone applied at a rate of 2 pounds/acre in the spring of 1986, planting in spring of 1986
	P2S-F86	Pronone applied at a rate of 2 pounds/acre in the spring of 1986, planting in fall of 1986
	P2F-F86	Pronone applied at a rate of 2 pounds/acre in the fall of 1986, planting in fall of 1986
	P2F-S87	Pronone applied at a rate of 2 pounds/acre in the fall of 1986, planting in spring of 1987
	P4F-F85	Pronone applied at a rate of 4 pounds/acre in the fall of 1985, planting in fall of 1985
	P4F-S86	Pronone applied at a rate of 4 pounds/acre in the fall of 1985, planting in spring of 1986
	P4S-S86	Pronone applied at a rate of 4 pounds/acre in the spring of 1986, planting in spring of 1986

Table 2. cont.

Trial	Abbreviation	Definition
1985	P4S-F86	Pronone applied at a rate of 4 pounds/acre in the spring of 1986, planting in fall of 1986
	P4F-F86	Pronone applied at a rate of 4 pounds/acre in the fall of 1986, planting in fall of 1986
	P4F-S87	Pronone applied at a rate of 4 pounds/acre in the fall of 1986, planting in spring of 1987
	O2S-S86	Oust applied at a rate of 2 ounces/acre in the spring of 1986, planting in spring of 1986
	O2S-F86	Oust applied at a rate of 2 ounces/acre in the spring of 1986, planting in fall of 1986
	O2F-F86	Oust applied at a rate of 2 ounces/acre in the fall of 1986, planting in fall of 1986
	O2F-S87	Oust applied at a rate of 2 ounces/acre in the fall of 1986, planting in spring of 1987
	O4S-S86	Oust applied at a rate of 4 ounces/acre in the spring of 1986, planting in spring of 1986
	O4S-F86	Oust applied at a rate of 4 ounces/acre in the spring of 1986, planting in fall of 1986
	O4F-F86	Oust applied at a rate of 4 ounces/acre in the fall of 1986, planting in fall of 1986
	O4F-S87	Oust applied at a rate of 4 ounces/acre in the fall of 1986, planting in spring of 1987
	C-F85	check, planted in the fall of 1985
	C-S86	check, planted in the spring of 1986
	C-F86	check, planted in the fall of 1986
	C-S87	check, planted in the spring of 1987

herbicide treatment plots per block were re-measured during the latest re-measurement. The re-measured herbicide treatment plots were treated with broadcast applications of Velpar L herbicide at a rate of two and four pounds a.i./acre in the spring and fall of 1983. Up to four rows of 20 lodgepole pine and three rows of 20 western larch seedlings each were planted on two feet spacings at various times from the spring of 1983 through the spring of 1984. Up to three lodgepole pine seedling rows/planting dates per treatment plot were re-measured. Re-measured planting dates include a spring planting before and a spring planting after a spring herbicide application in 1983 and a fall planting after a spring and fall herbicide application in 1983. The spring planting date after spring herbicide application was not measured at Boyd Mountain. Embedded within planting season was a stock type variation; spring planting dates used 2-0 bare root stock and the fall planting date used 1-0 container stock. Seedlings were planted on a two feet by two feet spacing. Further trial detail may be found in McLeod and Mandzak (1990).

1985 Trial

The objective of the 1985 trial was to determine the efficacy of herbicide HVC in controlling herbaceous vegetation and promoting western larch and lodgepole pine survival and growth on four sites with different soil characteristics (Thamarus and Milner 1989). Thamarus and Milner (1989) and on-site verification by the author provided the following trial information. All four sites were re-measured in the fall of 1996 and summer of 1997. Herbicide type, application rate and season, seedling stock type and planting date were factors of interest. Species included lodgepole pine at Gold Creek and lodgepole pine and western larch at Smiley Creek, Lost Prairie, and Bear Creek.

Replication at each site consisted of three blocks. Within each block, four (Gold Creek) and eight (Bear Creek, Lost Prairie, and Smiley Creek) herbicide treatment plots and one check plot were assigned at random. Herbicides included Pronone 10G, a granular form of 10% hexazinone by weight, and Oust, a dispersible granule herbicide with the active ingredient sulfometuron methyl. Herbicide rates included two and four pounds a.i./acre Pronone and two and four ounces a.i./acre Oust. Broadcast applications of herbicides were applied during the fall of 1985 and spring of 1986 at Gold Creek and during the spring and fall of 1986 at the other three sites. The herbicide type, rate and season of application defined the HVC treatment.

Each herbicide treatment and check plot was subdivided into two planting dates, representing a planting during the same season of herbicide application as well as a planting with a season delay. For example, seedlings were planted during the spring of 1986 and fall of 1986 within the 1986 spring herbicide application treatment plot. Planting dates at Gold Creek occurred during fall of 1985, spring of 1986 and fall of 1986. At the other three sites, planting occurred during the spring of 1986, fall of 1986, and spring of 1987.

Within each planting date, two rows of 20 seedlings each were planted. In Pronone treated plots, each planting date was comprised of one row of 2-0 bare root lodgepole pine seedlings and one row of 1-0 container lodgepole pine seedlings. Within Oust treated plots one row of 2-0 bare root lodgepole pine seedlings and one row of 1-0 container western larch seedlings were planted. Seedlings were planted on two feet by two feet spacing at Bear Creek and Smiley Creek and a two feet by four feet spacing at Gold Creek and Lost Prairie. The growth of lodgepole pine seedlings in the Oust treatments is not reported. Check plots contained all planting date and stock type factor combinations used in the treated plots. For more detailed trial descriptions, see Thamarus and Milner (1988) and Thamarus and Milner (1989).

1996-1997 Measurements

Measurement of the 1985 trial began in the fall of 1996 and finished in the summer of 1997. Trials 1981 and 1983 were measured in the summer of 1997. Basal diameter, diameter at breast height (DBH), total height, and damage if present were measured on surviving trees in all trials. Basal diameter was measured at 0.5 feet above ground level and/or above any swell. DBH was measured at 4.5 feet on the uphill side of the tree. Basal diameter and DBH were measured to the nearest tenth of an inch. The total height measurement included the 1996 season's growth for the 1981 and 1985 trials. In the 1983 trial, the total height measurement included the 1997 season's growth. Total height was measured to the nearest tenth of a foot using a telescoping height pole. Tree volume, in cubic inches, was calculated from basal diameter and total height using the formula for a cone. Plot survival and plot volume, the sum volume of surviving trees per treatment factor combination, were calculated for the 1983 and 1985 trials. Plot volume reflects the size of individual trees combined with survival. Plot survival and plot volume were not calculated for the 1981 trial due to destructive sampling in unknown treatments.

Within each trial, non-destructive stem analyses for annual height at the end of each growing season since planting were performed on a 20% random sample of the number of planted seedlings per HVC and and HVC-planting date treatment combination. Up to six trees per treatment combination (shade x HVC) were measured in the 1981 trial and up to four trees per treatment combination were measured for the 1983 (HVC x planting date) and 1985 (HVC x planting date x stock type) trials, respectively. In some cases, high mortality limited the number of sampled trees. Annual heights were determined by counting the internodes back from the current years height using a telescoping height pole. Tree form and branch internodes aided in determining annual height. Three periodic height growth increments were calculated per trial from these measurements to the nearest tenth of a foot. Equal periodic growth increments were sought for the three periods within a trial.

Surface vegetation was sampled on 3.28 feet by 3.28 feet square plots centered on each stem analysis sample tree. If survival was less than 20%, additional surface vegetation plots were randomly chosen along the planting row to obtain a 20% sample resulting in six vegetation plots per treatment combination in the 1981 trial and four vegetation plots per treatment combination in the 1983 and 1985 trials, respectively. Ocular estimates of percent cover were determined by lifeform on each surface vegetation plot. Lifeform categories included high shrub (greater than three feet tall), low shrub (less than three feet tall), forb, and grass/sedge. Total cover was calculated by summing the lifeform cover percentages per surface vegetation plot.

Statistical Analyses

Analyses were conducted to determine how HVC treatments affected the long term development of planted tree seedlings and associated surface vegetation. Plot, tree and surface vegetation responses were analyzed. Mean annual height trends by the various treatment combinations were displayed graphically. ANOVA F-tests and Duncan's Multiple Range tests (DMR) were performed for mean plot survival, plot volume, tree DBH, tree height, periodic tree height growth, tree volume, percent grass cover and percent total cover. Appropriate analyses were performed with SPSS and SAS statistical software packages as outlined for a particular experimental design in Steel and Torrie (1980). Various combinations of HVC treatments and planting dates were used to define treatments within trials, see Table 2 for treatment combination definitions. A significance level of 0.05 was used for all analyses. Detailed trial analyses are described below.

1981 Trial

Analyses for this trial were conducted on mean tree and surface vegetation responses to HVC and shade treatments represented in the experimental design at each site (Table 3). Factors included shade card and HVC treatments. Tree responses included DBH, total height, annual height, periodic height growth, and volume. Periodic height growth was calculated in one, six year interval ('81-'86) and two, five year intervals ('87-'91, and '92-'96). Preliminary ANOVA F-tests for a split plot design as seen in Table 2, were conducted using SAS for total tree height to determine significant factors for further tree analyses. Random samples from all surviving trees and the stem analysis samples were obtained from pooled observations across non-significant factors. Treatment means for tree responses were calculated from the appropriate pooled dataset. Mean annual total height by pooled treatment combination was displayed graphically by site.

Surface vegetation responses included mean cover percentages by lifeform and a total cover percentage. Shade card treatments were deemed unimportant in affecting surface vegetation cover. Forty-six surface vegetation plots per herbicide treatment plot at each site were used in calculating mean cover percentages by lifeform.

ANOVA F-tests and DMR tests were performed in SPSS under a fixed factor design for DBH, total height, periodic height growth, volume, grass cover, and total cover at each site for the pooled dataset. Grass cover was transformed using the arcsine transformation for proportions prior to analysis (Sokal and Rohlf 1987).

Table 3. ANOVA table structure for preliminary analyses on tree height for the two locations in the 1981 trial. Degrees of freedom (df) for each factor are displayed.

Location	**Cow Creek**	**Murr Creek**
Source	**df**	**df**
whole plot		
block(b)	3	3
shade card (s)	1	1
b x s (error)	3	3
subplot		
HVC treat. (t)	5	4
s x t	5	4
error	590	573
total*	607	588

* based on surviving trees

1983 Trial

Plot and tree analyses were conducted by fall or spring planting season within both sites for a total of four analysis groups. This was done to alleviate stock type differences by planting season. Analyses for this trial were conducted on mean plot, tree, and surface vegetation responses to the various treatment combinations represented in the analysis groups at each site. Analysis groups included a spring planting at Gold Creek (GCS) and Boyd Mountain (BMS) and a fall planting at Gold Creek (GCF) and Boyd Mountain (BMF). In the spring planting analysis group at Gold Creek (GCS), herbicide rate and planting date (before and after the spring herbicide application) defined the treatment combinations. Only one planting date was measured in the spring planting analysis group at Boyd Mountain (BMS) resulting in treatment combinations being defined by herbicide rate alone. In the fall planting analysis groups (GCF and BMF), herbicide application rate and season of application determined the treatment combinations.

Plot responses included mean survival and volume. ANOVA F-tests and DMR tests were performed for these variables in a factorial design using SPSS for all analysis groups. The blocking factor was not included in the analyses in order to provide replication for each plot level treatment combination.

Tree responses included DBH, total height, annual height, periodic height growth, and volume. Periodic height growth was calculated in three, five year intervals ('83-'87, '88-'92, and '93-'97). Preliminary ANOVA F-tests using a randomized complete block design (Table 4) for the treatment combinations were conducted on total tree height to determine if blocking was significant within each analysis group. If blocking was not significant, observations were combined into a pooled dataset. Random samples from all surviving trees and the stem analysis trees were obtained from the pooled dataset for each analysis group and treatment means were calculated. Mean annual total height by treatment combination was displayed graphically for each analysis group. Subsequent ANOVA F-tests and DMR tests were performed under a fixed factor design (GCS) and a randomized complete block design (BMS, GCF, BMF) for DBH, total height, periodic height growth, and volume for all analysis groups using SPSS.

Surface vegetation responses included mean cover percentages by lifeform and a total cover percentage. A total of twelve surface vegetation plots per herbicide treatment plot at each location were used in calculating mean cover percentages by lifeform. ANOVA F-tests and DMR tests were performed using SPSS for a randomized complete block design for grass and total cover. Grass cover was transformed using the arcsine transformation for proportions prior to analysis (Sokal and Rohlf 1987).

Table 4. ANOVA table structure for preliminary analyses on tree height for each planting season at the two locations in the 1983 trial. Degrees of freedom (df) for each factor are displayed.

Location	**Gold Cr.**	**Boyd Mt.**	**Gold Cr.**	**Boyd Mt.**
Planting Season	**Spring**	**Spring**	**Fall**	**Fall**
Source	**df**	**df**	**df**	**df**
block(b)	2	2	2	2
HVC treat. comb. (t)	5	2	4	4
b x t	10	3	8	8
error	132	87	181	207
total*	149	94	195	221

* based on surviving trees

1985 Trial

Prior to performing any analyses the Oust® treatments applied to lodgepole pine seedlings were omitted due to lack of early vegetation control. Western larch treatments at Lost Prairie and Bear Creek were omitted due to extreme mortality, (less than five trees alive per trial). Analyses were performed by species for mean plot, tree and surface vegetation responses to various treatment combinations. The treatment combinations were a combination of herbicide rate, season of application, and seedling planting date. Preliminary ANOVA F-tests on total tree height were conducted in a step-wise manner to determine stock type significance (split plot design, Table 5) and blocking significance (randomized complete block design) for the various treatment combinations at each site. Further analyses were separated by stock type, if significant, and pooled across blocks when blocking was non-significant.

Plot responses included mean survival and volume by treatment factor combination. ANOVA F-tests and DMR tests were performed for these variables in a factorial design in SPSS for stock types at all sites. The blocking factor was not included in the analyses in order to provide replication for each plot level treatment combination.

Tree responses included DBH, total height, annual height, periodic height growth, and volume. Periodic height growth was calculated in one, 2-3 year interval (-'88), and two, four year intervals ('89-'92 and '93-'96). If blocking was significant, means of surviving trees were calculated by block and treament combination. ANOVA F-tests and DMR tests were performed on these means using SPSS for a factorial design. The blocking factor was not included in the analyses in order to provide replication at each site. This was done to address high mortality rates in some HVC-planting date treatment combinations, which would not have allowed equal sample sizes to be obtained. If blocking was not significant, observations were combined into a pooled dataset. Random samples from all surviving trees and the stem analysis trees were obtained. ANOVA F-tests and DMR tests were performed under a fixed factor design for DBH, total height, periodic height growth, and volume for the stock types at each site using SPSS. Mean annual total height for chosen HVC-planting date treatment combinations were displayed graphically by site.

Surface vegetation responses included mean cover percentages by lifeform and a total cover percentage. A total of 24 surface vegetation plots per herbicide treatment plot at each location were used in calculating mean cover percentages by lifeform. ANOVA F-tests and DMR tests were performed using SPSS for a randomized complete block design for grass and total cover. Grass cover was transformed using the arcsine transformation for percentages prior to analysis (Sokal and Rohlf 1987).

Table 5. ANOVA table structure for preliminary analyses on tree height for each species at all locations in the 1985 trial. Degrees of freedom (df) for each factor are displayed.

Location	**Bear Cr.**	**Gold Cr.**	**Lost Prairie**	**Smiley Cr.**	**Smiley Cr.**
Species*	**(lpp)**	**(lpp)**	**(lpp)**	**(lpp)**	**(wl)**
Source	**df**	**df**	**df**	**df**	**df**
whole plot					
block(b)	2	2	2	2	2
HVC treat. comb. (t)	10	10	10	10	2
b x t (error)	20	20	19	20	4
subplot					
stock type (s)	1	1	1	1	---
t x s	10	10	10	10	---
error	434	766	471	992	12
total†	477	809	513	1035	20

* - lpp is lodgepole pine, wl is western larch
†- based on surviving trees

Results

1981 Trial

Blocking and shade factors were found to be non-significant in the preliminary analyses; therefor, observations were pooled across these factors for further analysis. Velpar L herbaceous vegetation control increased ponderosa pine growth in the 1981 trial after 16 years (Table 6). Dissimilar letters following treatment means in Table 6 and subsequent tables indicate significant differences between treatment means within a site at a .05 significance level. Individual tree growth responses (DBH, height, and volume) was greater in the Velpar L HVC. The largest increases at Cow Creek came in the broadcast Velpar L treatments where mean tree DBH, height, and volume increased 44%, 21%, and 68%, respectively, over the check plots. At Murr Creek, the greatest increases came with the spot Velpar L. treatments with 35%, 28%, and 98% increases in mean tree

DBH, height and volume over the check plots. There were no discernable differences between spot and broadcast herbicide treatments. The handscalping treatment, while not significantly different from the check plot, showed decreased height and volume after 16 years by 4% and 21%, respectively.

Table 6. Summary of 16-year mean response of six tree attributes, by HVC treatment and site, for the 1981 trial. Statistically different (alpha = 0.05) means are represented by different letters per site.

		Tree Attribute					
	HVC	DBH	Height	Volume	Height Growth (ft/per)		
Site	Treatment*	(in)	(ft)	(in^3)	P1 (-'85)	P2 ('86-'90)	P3 ('91-96)
Cow Creek	BV	2.3 d	10.2 c	481.2 d	3.1 b	3.5 b	4.3 a
	SV	2.0 cd	9.3 b	407.8 cd	2.9 b	3.1 ab	4.0 a
	BR	1.8 bc	8.5 ab	340.4 bc	2.2 a	2.4 a	3.8 a
	C	1.6 ab	8.4 a	285.8 ab	2.3 a	2.9 ab	4.2 a
	SR	1.6 ab	8.4 a	270.6 ab	2.2 a	2.8 ab	3.8 a
	HS	1.6 a	8.1 a	224.7 a	2.2 a	2.5 a	3.6 a
Murr Creek	SV	3.5 b	14.8 b	1301.1 b	3.6 a	5.0 a	5.4 a
	BV	3.5 b	14.6 b	1258.4 b	4.8 b	5.1 a	5.5 a
	SR	2.8 a	12.1 a	835.7 a	2.9 a	4.3 a	5.2 a
	BR	2.8 a	11.8 a	792.4 a	3.7 a	4.9 a	5.9 a
	C	2.6 a	11.6 a	656.5 a	3.0 a	4.7 a	6.1 a

* - refer to Table 2 for HVC treatment definitions.

Annual height trends indicate increased early height growth at both sites for roughly 9 (Murr Creek) to 11 years (Cow Creek) in Velpar L treated plots (Figure 1). This age range corresponded to a mean tree height between 5.0 to 5.5 feet for trees in the check plots. This is signified by the diverging height curves of treated versus check plots soon after planting followed by a period of parallel height curves. During the time of diverging height curves, Velpar L treated plots accrued a two year advantage in height growth over check plots. Recent height curves are parallel at Cow Creek and are starting to converge at Murr Creek. Parallel height curves indicate similar annual height growth while converging curves indicate that check plots are growing faster than treated plots. If the height curves converge, there may be no long term benefits of herbaceous vegetation control on height growth. The height growth trends are further depicted in the periodic height growth analyses. Broadcast Velpar L treated plots showed increased height growth during period one and two at Cow Creek and during period one at Murr Creek (refer back to Table 6). The spot Velpar L treatment at Cow Creek had increased height growth during period one at Cow Creek. No significant mean height growth differences were found during period three at either site confirming the trends observed in the height curves (Figure 1).

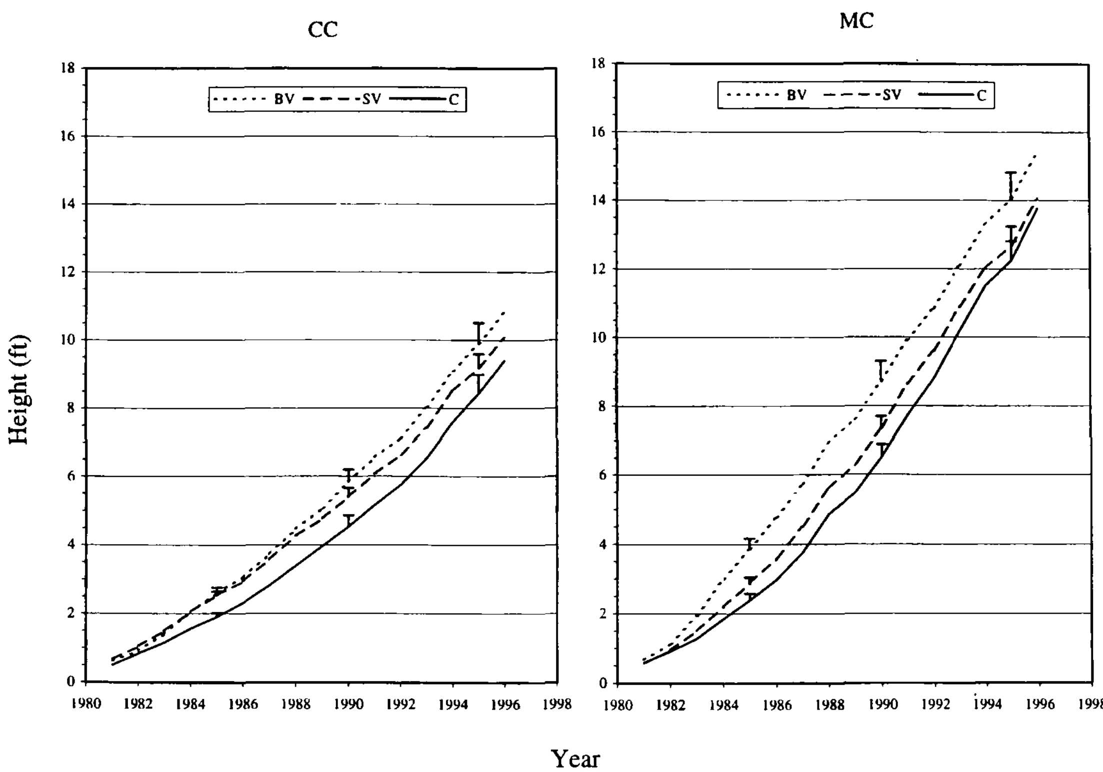

Figure 1. Ponderosa pine mean height curves (+1 SE), by treatment, at the Cow Creek (CC) and Murr Creek (MC) sites in the 1981 trial. See Table 2 for HVC treatment definitions.

The largest decrease in grass/sedge and total surface vegetation cover 16 years after treatment was found in the broadcast Velpar L control treatments (Table 7). Grass/sedge cover was 26% less on average and total coverage was 23% less for this treatment. The spot treatments of Velpar L and Roundup at Cow Creek also had less grass cover, but increases in forb and low shrub cover, respectively deleted the grass cover effects in the total cover amount. At Murr Creek, significant decreases in grass cover were maintained in the total cover amount for all but the spot Roundup treatments. There was no difference in grass/sedge and total cover for the handscalping treatment.

Table 7. Summary of five mean surface vegetation cover percentages, by HVC treatment and site, for the 1981 trial 16 years after treatment application. Statistically different (alpha = 0.05) means are represented by different letters per site.

		Surface Vegetation Cover (%)				
	HVC	Herbaceous		Shrub		
Site	Treatment*	Grass/Sedge	Forb	low	high	Total
Cow Creek	HS	27.4 d	16.1	40.1	2.6	86.2 c
	C	27.3 cd	12.0	37.3	1.0	77.5 bc
	SR	13.4 ab	11.8	45.2	0.0	70.4 ab
	SV	15.4 ab	18.9	35.0	0.6	69.9 ab
	BR	19.5 bc	11.0	37.3	0.0	67.8 ab
	BV	10.7 a	11.8	34.5	0.9	57.9 a
Murr Creek	C	48.2 d	24.7	20.7	0.5	94.1 c
	SR	21.3 bc	25.4	32.3	4.2	83.2 bc
	BR	25.9 c	19.8	33.5	0.0	79.2 ab
	SV	17.5 ab	24.2	25.2	1.3	68.1 a
	BV	13.5 a	20.5	31.4	2.2	67.6 a

* HVC treatments include broadcast Roundup (BR), broadcast Velpar L. (BV), hand scalp (HS), spot Roundup (SR), spot Velpar L. (SV), and a check plot (C).

1983 Trial

In the preliminary analysis, blocking was found to be significant in GCF, BMS, and BMF analysis groups, while non-significant in the GCS analysis group for tree responses. For the GCS group, observations were pooled across the blocking factor for further analysis.

Herbaceous vegetation control at both sites increased lodgepole pine tree growth over 14 years. Plot and tree responses for the spring and fall planting seasons at both sites are presented in Table 8. When comparing mean responses in the spring planting analyses at Gold Creek (GCS), treatments should be compared to the appropriate check plot. HVC treatments increased DBH, height, and tree volume up to 127%, 86%, and 501%, respectively, after 14 years across both sites. An increase from two to four pounds a.i./acre tended to have better results. For the best HVC treatments in the spring and fall planting at Gold Creek (GCS and GCF) and the fall planting at Boyd Mountain (BMF) height growth is still increasing as is evident in the diverging height curves (Figure 2). Significant differences in period three height growth support these trends for GCS and BMF but not GCF. The spring planting at Boyd Mountain has had parallel height curves since 1993 as well as non-significant period three height growth, both of which represent no differences in current height growth for the HVC treatments and the check plot trees. This age corresponded with a tree height of roughly 5.5 feet for the trees in the check plots.

Table 8. Summary of lodgepole pine mean plot, tree, and surface vegetation responses after 14 years, by HVC treatment factor combination, for the spring and fall planting dates, and site in the 1983 trial. Significant differences are denoted by different letters.

Spring Plant	HVC	-------- Plot -------		------------------------------ Tree			------------------------------		
	Treatment	Survival	Volume	DBH	HT	Vol.	------ Height Growth (ft/per) ------		
Site	Combination*	(%)	(in^3)	(in)	(ft)	(in^3)	P1 (-'86)	P2 ('87-'91)	P3 ('92-'97)
Gold	V4S-A	36.7 bc	5422.0 c	2.5 b	16.6 b	654.3 c	4.0 b	5.1 b	7.3 b
Creek	V2S-A	60.0 cd	3526.3 bc	2.0 b	14.0 b	370.3 b	3.7 b	4.3 b	6.1 ab
(GCS)	V2S-B	41.7 bc	3208.6 bc	2.0 b	14.1 b	369.9 b	3.5 b	3.9 b	6.2 ab
	V4S-B	15.0 a	1823.7 ab	2.4 b	15.8 b	607.9 bc	3.9 b	5.0 b	6.4 ab
	C-A	73.3 d	1719.1 ab	1.1 a	8.9 a	108.8 a	1.3 a	2.6 a	5.0 a
	C-B	23.3 ab	507.8 a	1.2 a	8.9 a	118.6 a	1.3 a	2.4 a	5.3 a
Boyd	V4S-B	31.7 a	3305.2 a	2.4 b	14.8 b	521.2 b	2.8 b	5.3 b	6.4 a
Mountain	V2S-B	41.7 a	2945.7 a	2.0 b	13.1 b	304.6 b	2.3 ab	4.2 ab	6.4 a
(BMS)	C	85.0 a	2611.5 a	1.4 a	10.4 a	143.7 a	1.5 a	3.2 a	5.4 a

Fall Plant	HVC	--------- Plot -------		------------------------------ Tree			------------------------------		
	Treatment	Survival	Volume	DBH	HT	Vol.	------- Height Growth (ft/per) ------		
Site	Combination*	(%)	(in^3)	(in)	(ft)	(in^3)	P1 (-'86)	P2 ('87-'91)	P3 ('92-'97)
Gold	V4S-A	81.7 b	6343.0 d	2.0 c	15.3 c	442.5 b	3.4 c	4.5 bc	7.4 a
Creek	V2F-A	68.3 ab	4651.2 c	2.0 c	14.5 c	388.9 b	2.4 b	3.9 b	6.7 a
(GCF)	V4F-A	51.7 a	3667.0 bc	2.0 c	14.9 c	366.6 b	2.3 b	4.7 c	6.8 a
	V2S-A	78.3 b	2621.6 b	1.4 b	12.1 b	161.0 a	2.4 b	3.8 b	6.2 a
	C	46.7 a	688.0 a	1.0 a	8.7 a	64.0 a	1.1 a	2.2 a	5.8 a
Boyd	V4S-A	66.7 a	5624.8 b	2.2 d	15.2 d	420.3 d	2.7 c	5.2 d	8.0 c
Mountain	V4F-A	70.0 a	4597.5 b	2.0 cd	13.2 c	352.7 cd	2.4 c	4.8 cd	6.7 b
(BMF)	V2S-A	86.7 a	3571.1 ab	1.6 b	11.8 b	183.6 b	2.3 c	3.8 b	6.1 b
	V2F-A	66.7 a	3420.3 ab	1.9 c	12.7 bc	289.3 c	1.7 b	4.2 bc	6.9 b
	C	80.0 a	987.5 a	1.0 a	8.3 a	71.6 a	1.1 a	2.8 a	4.7 a

* - refer to Table 2 for HVC treatment combination definitions.

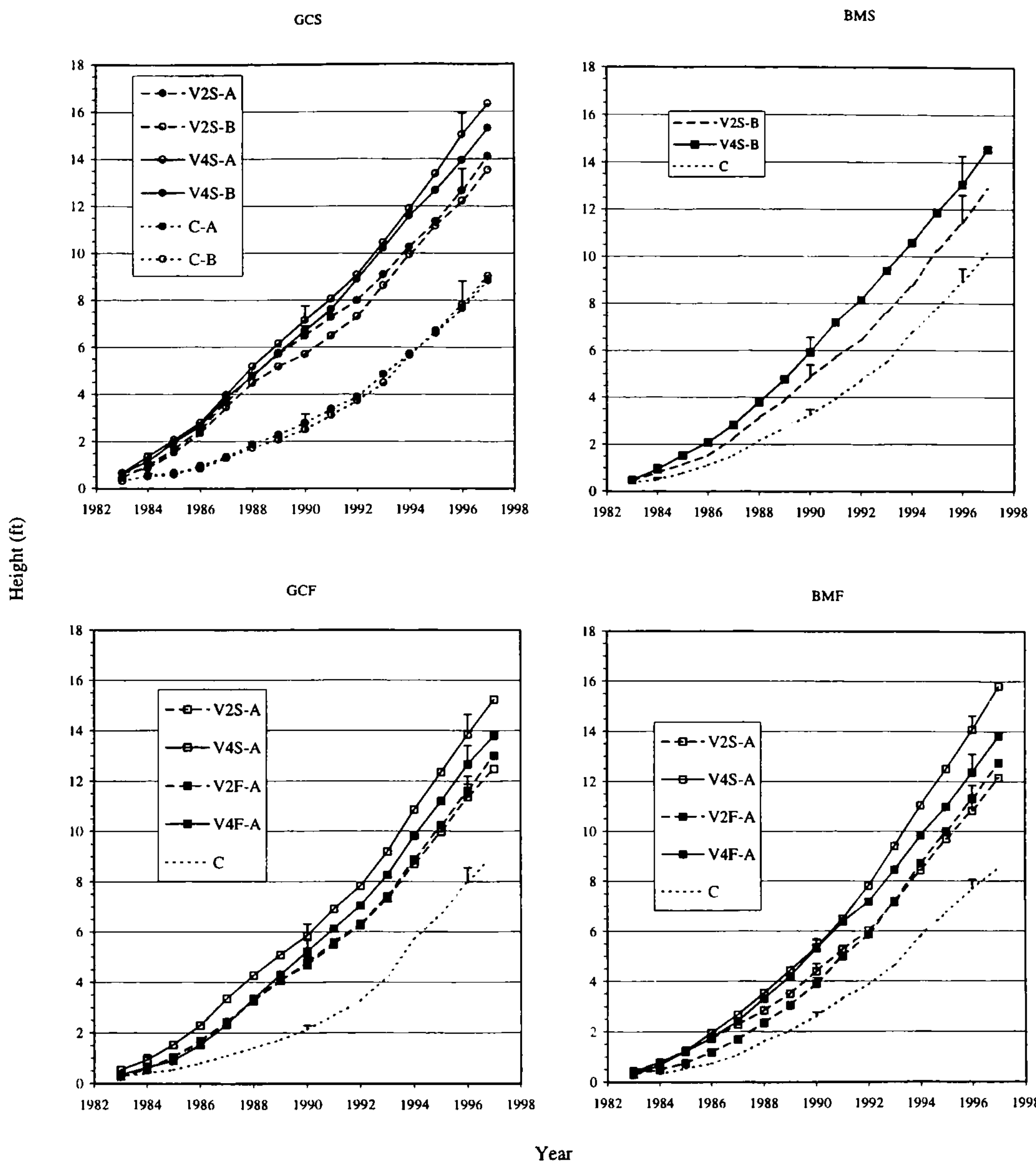

Figure 2. Lodgepole pine mean height curves (+ 1 SE), by treatment, for the Gold Creek analysis groups (GCS and GCF) and Boyd Mountain analysis groups (BMS and BMF) for the 1983 trial. See Table 2 for HVC-planting date treatment combination definitions.

Across analysis groups, these results display that HVC increased height growth for 10 to 14 years after HVC application. This has resulted in a three to five year height advantage for treated plots. Little to no differences in tree growth were evident from a planting season delay or whether or not planting occurred prior to or after herbicide application.

Significant increases in mean tree volume were sometimes negated in mean plot volume due to decreased survival in treated plots. For instance, increased tree volume in the spring planting at Boyd Mountain (BMS) was negated by decreased survival, resulting in non-significant plot volume totals. This also occurred in the spring planting at Gold Creek (GCS) for seedlings planted before the application of Velpar L four pounds a.i./acre and for seedlings planted after the spring application of Velpar L two pounds a.i./acre. Increases in plot volume up to 822% were seen when survival did not decrease.

For the treatment increasing plot volume by 822%, up to 73% of this increase was due to increased survival from a planting season delay; this treatment consisted of seedlings planted in the fall (GCF) after an application of Velpar L at four pounds a.i./acre in the spring at Gold Creek. There was no evidence of increased survival or plot volume from a planting season delay at Boyd Mountain. During spring planting at Gold Creek, planting before application of four pounds a.i./acre Velpar L. herbicide decreased plot survival compared to planting after treatment. Subsequently, plot volume was not significantly different than the check plot.

All HVC treatments had significantly less grass/sedge cover than the check plots 14 years after treatment at both sites (Table 9). The more effective vegetation control treatments, Velpar L at four pounds a.i./acre in the spring and fall, had greater decreases in grass cover than the two pounds a.i./acre treatments at Gold Creek. No grass/shrub cover differences between herbicide treatment rates were seen at Boyd Mountain. A decrease of 98% for grass/sedge cover was found in the fall application of four pounds a.i./acre Velpar L at Gold Creek. For the most part, decreased grass/sedge cover coincided with equal to slightly less forb and shrub cover in the treated plots. The lesser lifeform cover estimates were then additive in decreasing total cover of the treated plots. The exception was the fall application of two pounds a.i./acre of Velpar L (V2F) at Boyd Mountain. Season of herbicide application did not impact vegetation cover 14 years after application.

Table 9. Summary of five mean surface vegetation cover percentages by HVC treatment and site for the 1983 trial 14 years after herbicide application. Significant differences in cover are denoted by different letters for a response within a site.

		------- Surface Vegetation Cover (%) ------				
	HVC	**Herbaceous**		**Shrub**		
Site	**Treatment***	**Grass/Sedge**	**Forb**	**low**	**high**	**Total**
Gold Creek	C	43.8 c	16.1	30.9	0.0	90.8 c
	V2S	11.0 b	9.8	37.9	0.0	58.7 b
	V2F	7.2 b	19.3	25.7	0.0	52.2 ab
	V4S	1.1 a	9.1	34.9	0.0	45.1 ab
	V4F	0.7 a	15.4	26.3	0.0	42.4 a
Boyd Mountain	C	29.9 b	37.3	38.2	1.0	106.3 b
	V2F	16.3 a	30.0	36.3	0.0	82.6 ab
	V2S	8.4 a	17.6	47.3	0.0	73.3 a
	V4F	12.8 a	25.4	24.5	0.0	62.8 a
	V4S	14.1 a	25.8	17.6	0.0	57.4 a

* HVC treatments include Velpar L. applied at a rate of 2 pounds/acre in spring (V2S), Velpar L. applied at a rate of 2 pounds/acre in fall (V2F), Velpar L. applied at a rate of 4 pounds/acre in spring (V4S), Velpar L. applied at a rate of 4 pounds/acre in fall (V4F), and a check plot (C).

1985 Trial

In the preliminary analysis, stock type showed significant differences in mean tree height. Therefor, further analyses were separated by stock type within a site. Blocking was significant for bareroot stock at Gold Creek, Bear Creek, and Smiley Creek and for container stock at Gold Creek, and Smiley Creek. Appropriate analyses were subsequently used for further analyses as outlined in the Method section.

Lodgepole pine and western larch plot and tree responses and surface vegetation responses after 11 years at Gold Creek and after 10 years at Bear Creek, Lost Prairie, and Smiley Creek are presented in Tables 10 - 16. See Table 5 for treatment definitions. Tables 10 and 11 refer to responses of plot and individual lodgepole pine of 2-0 bare root stock, respectively. Tables 12 and 13 refer to responses of plot and individual lodgepole pine of 1-0 container stock, respectively. Tables 14 and 15 report western larch plot and tree responses, respectively. Table 16 reports surface vegetation responses by herbicide treatment plot at all sites.

Lodgepole Pine - Bare Root Stock

HVC increased the growth of individual 2-0 bare root lodgepole pine stock at all sites after 10 and 11 years. Herbicide rate was the major influence in determining growth benefits from herbaceous vegetation control. Increases of up to 200%, 88%, and 289% in tree DBH, height, and volume, respectively, over the check plots were found. The greatest increases came from treatment combinations with the Pronone four pounds a.i./acre rate at Gold Creek and Bear Creek and Lost Prairie. Only one treatment combination was significant at Smiley Creek and it was a Pronone four pound a.i./acre rate. The Pronone two pound a.i./acre rate showed mixed results with one (P2F-F85), one (P2S-S86), and three (P2S-S86, P2F-F86, and P2F-S87) treatment combinations being significantly greater than the check plots at Gold Creek, Bear Creek, and Lost Prairie, respectively. Compared to the higher rate, the two pound a.i./acre rate did not do as well at Gold Creek and Bear Creek. There was no difference between rates at Lost Prairie. A season delay in planting after herbicide application did not have any effect on individual tree growth after 10 years in Gold Creek, and at 11 years in Bear Creek and Smiley Creek. Only tree volume increased after 11 years at Lost Prairie.

Most herbicide treatment combinations that produced early height growth advantages continue to do so at Gold Creek, Bear Creek, and Lost Prairie. This can be seen in the significantly greater height growth during periods two and three. Height curves in Figures 3, 4, and 5 also show these results. These figures depict the best growth advantages of both stock types compared to their appropriate check plots for all four pounds a.i./acre HVC-planting date treatment combinations. It should be noted that these lines are still diverging for the bare root stock and container stock. These results indicate that HVC increased height growth for at least six to seven years after application. This has resulted in a three to four year height advantage for treated plots.

Increases in individual tree growth were carried through to plot volume totals. This was due to non-significant (Gold Creek, Lost Prairie, and Smiley Creek) or greater increases (Bear Creek) in survival with herbicide treatments. The four pounds a.i./acre rate did not harm seedling survival as was the case in some of the Velpar L pounds a.i./acre treatments in the 1983 trial. Again, the higher rate increased plot volumes. Survival was not impacted by planting season delay at any site.

Table 10. Summary of mean lodgepole pine plot responses for 2-0 bare root stock by HVC-planting date treatment combination at four sites after 10 to 11 years for the 1985 trial. Significant differences are denoted by different letters within a site.

Site	HVC Treatment Combination*	Survival (%)	Volume (in3)
Gold Creek	P4S-S86	75.0 a	2939.0 d
	P4F-F85	75.0 a	1939.7 c
	P4S-F86	95.0 a	1887.8 bc
	P2F-F85	81.7 a	1755.6 bc
	P4F-S86	53.3 a	1554.8 bc
	P2F-S86	91.7 a	1551.5 bc
	P2S-S86	85.0 a	1219.2 abc
	P2S-F86	98.3 a	979.0 ab
	C-F85	96.7 a	958.9 ab
	C-S86	56.7 a	572.9 a
	C-F86	75.0 a	465.1 a
Bear Creek	P4F-S87	71.7 ef	5246.1 e
	P4S-S86	63.3 cde	4124.6 de
	P2S-S86	76.7 ef	3552.8 cd
	P2F-S87	83.3 f	3369.3 cd
	P4S-F86	68.3 def	2457.9 bc
	P2F-F86	65.0 def	1727.4 ab
	P4F-F86	36.7 bcd	1517.9 ab
	P2S-F86	45.0 cde	1203.3 ab
	C-S86	6.7 a	605.3 a
	C-S87	25.0 abc	399.5 a
	C-F86	13.3 ab	134.5 a
Lost Prairie	P4S-S86	70.0 a	6796.7 d
	P4F-S87	70.0 a	4512.1 c
	P4F-F86	55.0 a	3627.8 bc
	P2S-S86	35.0 a	2528.2 bc
	P4S-F86	75.0 a	2393.9 bc
	P2F-F86	41.7 a	2277.2 bc
	P2S-F86	53.3 a	1953.9 bc
	C-S86	38.3 a	1790.2 bc
	P2F-S87	35.0 a	1715.8 bc
	C-F86	55.0 a	1282.8 b
	C-S87	30.0 a	554.7 a
Smiley Creek	P4S-S86	83.3 a	4403.1 c
	C-S86	83.3 a	3574.1 bc
	P4F-F86	88.3 a	3278.0 bc
	P4F-S87	90.0 a	3132.2 bc
	P2S-S86	91.7 a	2943.9 bc
	P4S-F86	95.0 a	2755.0 bc
	P2F-F86	95.0 a	2659.7 bc
	C-F86	96.7 a	2158.1 ab
	P2S-F86	95.0 a	2115.2 ab
	P2F-S87	86.7 a	2019.1 ab
	C-S87	75.0 a	924.5 a

* - refer to Table 2 for HVC-planting date treatment combination definitions.

Table 11. Summary of mean lodgepole pine tree responses for 2-0 bare root stock by HVC-planting date treatment combination after 10 to 11 years for the 1985 trial. Significant differences are denoted by different letters within a site.

Site	HVC Treatment Combination*	DBH (in)	Height (ft)	Volume (in^3)	------- Height Growth (ft/per) ------ P1 (-'88)	P2 ('89-92)	P3 ('93-96)
Gold Creek	P4S-S86	1.5 f	10.7 e	204.7 e	2.1 d	3.5 d	4.9 d
	P4F-S86	1.4 ef	9.6 de	148.7 de	1.7 cd	3.0 cd	4.3 bcd
	P4F-F85	1.2 def	9.1 de	135.8 d	1.8 cd	3.0 cd	4.7 cd
	P2F-F85	1.1 cde	8.6 cd	119.0 cd	1.9 cd	3.0 cd	4.6 cd
	P4S-F86	1.1 cde	9.0 de	99.0 bcd	1.4 bc	2.6 c	4.7 cd
	P2F-S86	1.0 cd	8.2 bcd	88.6 abcd	1.7 cd	2.3 abc	4.3 bcd
	P2S-S86	0.9 bc	7.1 abc	72.4 abc	1.5 c	2.4 bc	4.1 bc
	C-S86	0.7 ab	6.2 a	52.6 ab	0.9 ab	1.5 a	3.7 ab
	C-F85	0.7 ab	6.4 a	50.7 ab	1.0 ab	1.7 ab	3.7 ab
	P2S-F86	0.7 ab	6.7 ab	49.9 ab	0.9 ab	1.8 ab	3.7 ab
	C-F86	0.5 a	5.4 a	31.8 a	0.6 a	1.5 a	3.2 a
Bear Creek	C-S86	2.0 †	13.4 †	460.2 †	1.6 †	4.0 †	7.8 †
	P4F-S87	2.0 e	13.7 e	375.0 d	1.3 de	5.0 d	6.9 cd
	P4S-S86	1.9 de	13.5 e	343.1 d	2.0 f	4.8 cd	7.2 d
	P4F-F86	1.6 cd	11.5 de	232.0 c	1.3 de	4.4 bcd	6.6 cd
	P2S-S86	1.6 cd	11.2 cd	220.8 bc	1.2 cde	3.5 bc	6.1 abcd
	P2F-S87	1.5 bc	11.0 cd	194.2 bc	1.2 cde	3.7 bcd	6.7 cd
	P4S-F86	1.5 bc	11.6 de	179.4 bc	1.4 e	3.9 bcd	6.6 cd
	P2F-F86	1.1 ab	9.2 bc	133.8 ab	0.8 abc	3.0 ab	6.2 bcd
	P2S-F86	1.1 ab	9.5 cd	126.4 ab	0.9 bcd	2.9 ab	5.7 abc
	C-S87	1.0 a	7.3 ab	80.5 a	0.5 ab	2.0 a	4.8 ab
	C-F86	0.8 a	6.7 a	45.4 a	0.4 a	1.7 a	4.7 a
Lost Prairie	P4S-S86	2.2 d	13.9 f	456.0 f	2.7 e	4.9 d	6.7 c
	P2S-S86	2.0 cd	12.7 def	367.3 ef	2.2 de	4.5 d	6.7 c
	P4F-F86	2.0 cd	13.3 ef	330.1 de	1.7 cd	4.3 cd	6.0 abc
	P2F-F86	1.9 c	12.0 cde	299.3 de	1.6 bc	3.4 bc	6.6 c
	P4F-S87	1.8 c	12.8 def	290.9 de	2.2 de	4.4 cd	6.9 c
	P2F-S87	1.8 c	11.4 cde	245.4 cd	1.6 bc	2.9 ab	6.7 c
	C-S86	1.8 c	11.2 cd	228.0 bcd	1.6 bc	3.4 bc	6.3 bc
	P2S-F86	1.4 b	11.1 bcd	172.6 abc	1.9 cd	3.5 bc	6.4 bc
	P4S-F86	1.3 ab	10.2 abc	137.4 ab	1.8 cd	3.4 bc	6.5 c
	C-F86	1.2 ab	9.4 ab	129.7 ab	1.1 ab	2.5 ab	5.3 ab
	C-S87	1.1 a	8.6 a	92.5 a	0.9 a	2.1 a	5.2 a
Smiley Creek	P4S-S86	1.6 d	12.9 d	264.4 d	2.2 a	4.6 c	6.2 a
	C-S86	1.5 cd	11.6 bcd	197.0 cd	1.5 a	3.9 bc	6.1 a
	P4F-F86	1.4 bcd	11.6 bcd	186.8 bc	1.8 a	4.4 c	5.5 a
	P4F-S87	1.4 bcd	12.2 cd	173.6 bc	1.8 a	4.5 c	5.8 a
	P2S-S86	1.4 bcd	11.3 bcd	162.3 bc	1.9 a	3.4 ab	5.3 a
	P4S-F86	1.4 bcd	11.9 bcd	147.5 bc	1.5 a	4.4 c	5.7 a
	P2F-F86	1.3 cb	10.7 abc	138.2 bc	1.8 a	3.4 ab	5.5 a
	P2F-S87	1.2 abc	10.2 ab	116.6 ab	1.3 a	3.4 ab	5.8 a
	C-F86	1.2 abc	10.8 abc	111.9 ab	1.3 a	3.4 ab	6.0 a
	P2S-F86	1.2 ab	10.7 abc	111.6 ab	1.6 a	3.9 bc	5.3 a
	C-S87	0.9 a	9.0 a	60.2 a	1.0 a	2.8 a	6.0 a

* - refer to table 2 for HVC-planting date treatment combination definitions.

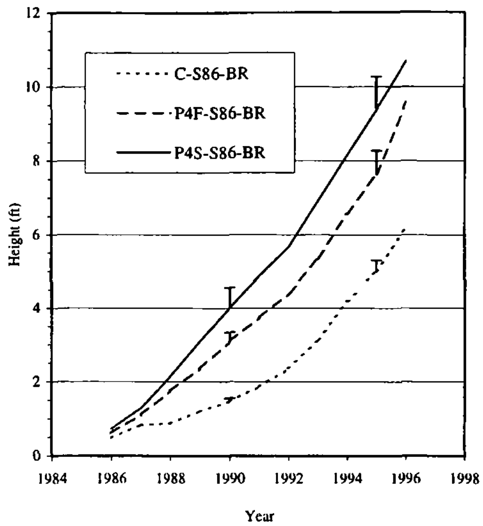

Figure 3. Lodgepole pine mean height curves (+1 SE), by treatment, for the spring 1986 planting dates at Gold Creek in the 1985 trial. 2-0 bare root stock (-BR) is presented. See Table 2 for HVC-planting date treatment combination definitions.

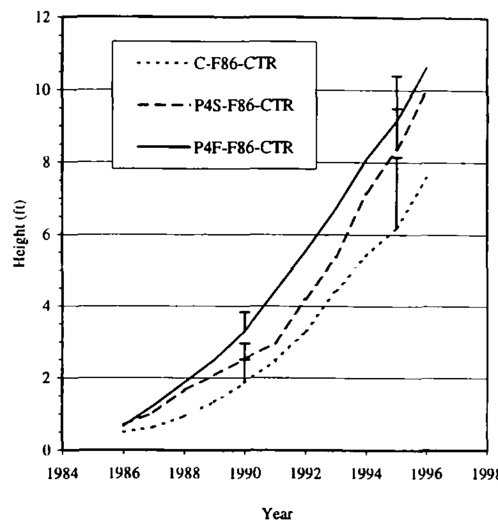

Figure 4. Lodgepole pine mean height curves (+1 SE), by treatment, for the fall 1986 planting dates at Lost Prairie in the 1985 trial. 1-0 container stock (-CTR) is presented. See Table 2 for HVC-planting date treatment combination definitions.

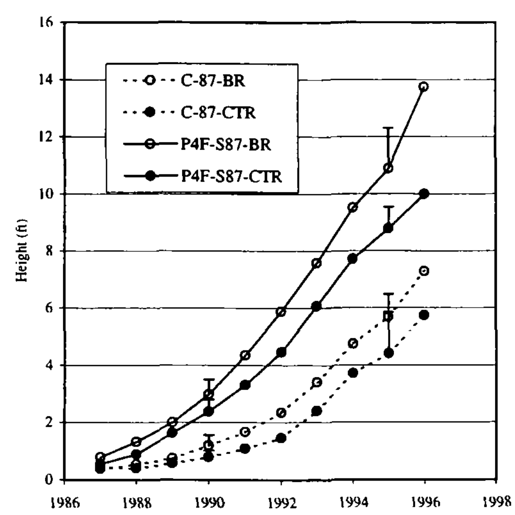

Figure 5. Lodgepole pine mean height curves (+1 SE), by treatment, for the spring 1987 planting dates at Bear Creek in the 1985 trial. 2-0 bare root (-BR) and 1-0 container (-CTR) stock are presented. See Table 2 for HVC definitions.

Lodgepole Pine - Container Stock

Container stock of lodgepole pine did not fare as well as the bare root stock. Fewer differences in individual tree growth were noted at Gold Creek, Bear Creek, and Lost Prairie (Table 13). As was the case with the bare root stock, the four pounds a.i./acre treatments did better than the two pounds a.i./acre treatments. Tree dbh, height, and volume increased up to 175%, 123%, and 502% greater , respectively, over the check plots. Planting season in relation to the herbicide application season did not impact tree growth.

Annual height growth trends are cloudy for the container stock. While period three height growth is not significant across all sites, the height curves are still diverging between the best treatments and the check plot trees (Figures 4 and 5). Small sample sizes may be corrupting the ability to use statistics for determining statistical differences in period three height growth. Currently, herbicide application has yielded up to a four-year height advantage for HVC treated plots.

Survival was not heavily impacted by herbicide treatments after 10 and 11 years (Table 12). Only two out of nine HVC treatments increased survival at Gold Creek (P4S-F86 and P2S-F86) and Bear Creek (P4F-F86 and P4S-F86). The only other significant differences in survival were found at Smiley Creek where two treatments (P4S-S86 and P4F-F86) decreased lodgepole pine survival. With the lack of impact on survival most treatments with increased individual tree growth, relayed those increases to plot volume totals. Thus, three out of nine treatments per site reported increases in plot volume at Gold Creek after 10 years and Bear Creek and Lost Prairie after 11 years. Only one HVC treatment and planting date combination increased plot volume of container stock at Smiley Creek (P4F-S87).

Table 12. Summary of mean lodgepole pine plot responses for 1-0 container stock by HVC-planting date treatment combination at four sites after 10 to 11 years for the 1985 trial. Significant differences are denoted by different letters within a site.

Site	HVC Treatment Combination*	Survival (%)	Volume (in3)
Gold Creek	P4S-F86	90.0 d	1699.8 e
	P4F-S86	51.7 c	1284.2 de
	P2S-F86	91.7 d	1094.7 cde
	P2F-S86	41.7 bc	795.3 bcd
	P2S-S86	50.0 c	706.4 abcd
	P4S-S86	15.0 ab	534.4 abc
	C-S86	41.7 bc	335.9 ab
	C-F86	50.0 c	181.5 ab
	P2F-F85	10.0 ab	143.6 ab
	P4F-F85	10.0 a	141.8 ab
	C-F85	6.7 a	86.7 a
Bear Creek	P4S-S86	35.0 cd	2361.2 d
	P2S-S86	41.7 d	1655.7 cd
	P4F-S87	41.7 d	1405.8 bc
	P4S-F86	25.0 cd	781.4 abc
	P2F-S87	36.7 cd	703.1 abc
	C-S86	15.0 abcd	515.8 ab
	P4F-F86	11.7 abc	239.6 a
	P2S-F86	13.3 abc	214.6 a
	C-F86	1.7 a	141.5 a
	C-S87	10.0 abc	72.4 a
	P2F-F86	8.3 ab	66.9 a
Lost Prairie	P2S-S86	48.3 d	3036.7 b
	P4S-S86	31.7 cd	2260.0 b
	P4F-S87	51.7 d	2160.7 b
	C-S86	31.7 cd	1145.5 a
	P4F-F86	26.7 abcd	809.3 a
	P4S-F86	16.7 abc	705.8 a
	P2F-S87	28.3 bcd	704.3 a
	C-S87	41.7 cd	482.2 a
	P2S-F86	8.3 abc	244.4 a
	P2F-F86	5.0 ab	218.7 a
	C-F86	6.7 a	114.6 a
Smiley Creek	P4S-S86	56.7 b	2238.3 e
	C-S86	86.7 cd	2051.0 de
	P2S-S86	75.0 bcd	1843.4 cde
	P4S-F86	76.7 bcd	1716.4 bcde
	P4F-S87	71.7 bcd	1413.4 abcde
	P2F-S87	73.3 bcd	1286.4 abcd
	C-S87	90.0 d	1026.0 abc
	P2F-F86	60.0 b	940.6 ab
	P4F-F86	33.3 a	804.3 a
	P2S-F86	58.3 b	784.4 a
	C-F86	70.0 bc	759.5 a

* - refer to Table 2 for HVC-planting date treatment combination definitions.

Table 13. Summary of mean lodgepole pine tree responses for 1-0 container stock by HVC-planting date treatment combination after 10 to 11 years for the 1985 trial. Significant differences are denoted by different letters within a site.

Site	HVC Treatment Combination*	DBH (in)	Height (ft)	Volume (in^3)	------- Height Growth (ft/per) ------ P1 (-'88)	P2 ('89-92)	P3 ('93-96)
Gold Creek	P4S-S86	1.3 c	9.8 e	178.5 d	1.9 d	3.8 d	4.4 a
	P4F-S86	1.2 bc	9.4 de	124.8 cd	1.6 cd	3.0 bcd	4.1 a
	P2F-S86	1.0 abc	8.1 cde	108.8 bc	1.5 bcd	2.4 abc	4.2 a
	P4S-F86	1.1 abc	8.7 cde	94.0 bc	1.2 abc	3.3 cd	4.9 a
	P4F-F85	0.9 †	6.8 †	70.9 †	0.9 †	1.8 †	3.7 †
	P2S-S86	0.8 ab	7.0 bc	70.4 abc	1.1 abc	1.9 ab	3.8 a
	P2F-F85	0.8 ab	7.6 bcde	67.2 abc	1.1 abc	2.5 abc	4.3 a
	C-F85	1.1 †	5.9 †	65.0 †	0.7 †	1.8 †	3.4 †
	P2S-F86	0.8 ab	6.4 bc	54.7 ab	0.9 ab	2.2 abc	4.3 a
	C-S86	0.6 a	5.3 ab	48.2 ab	0.9 ab	1.3 a	3.3 a
	C-F86	0.4 †	3.9 a	15.6 a	0.5 a	1.2 a	2.7 a
Bear Creek	C-F86	2.1 †	13.2 †	424.4 †	0.7 †	4.3 †	8.2 †
	P4S-S86	1.9 c	12.5 c	334.2 c	2.1 d	5.2 c	6.5 a
	P2S-S86	1.5 bc	10.9 bc	199.0 b	1.3 b	3.5 b	5.8 a
	C-S86	1.4 †	7.6 ab	171.1 ab	1.2 †	3.7 †	4.6 †
	P4F-S87	1.4 abc	10.0 bc	166.0 ab	0.9 ab	3.6 b	6.1 a
	P4S-F86	1.4 †	11.0 †	160.6 †	1.5 †	3.9 †	6.5 †
	P4F-F86	1.0 ab	9.0 abc	94.3 ab	0.8 ab	2.8 b	5.4 a
	P2F-S87	1.1 ab	8.3 ab	87.6 ab	0.8 ab	2.9 b	5.9 a
	P2S-F86	1.0 †	8.1 †	85.2 †	1.0 †	2.3 †	5.2 †
	P2F-F86	0.9 a	7.2 ab	53.5 a	0.8 ab	2.6 ab	4.5 a
	C-S87	0.8 †	5.7 a	36.2 a	0.4 a	1.2 a	4.3 a
Lost Prairie	P2S-S86	2.2 d	13.4 b	393.0 c	1.8 ab	4.4 a	6.5 a
	P4S-S86	2.1 cd	13.3 b	366.9 c	2.9 b	4.7 a	6.3 a
	P2F-F86	1.7 bcd	11.7 b	218.7 bc	1.6 ab	3.2 a	6.9 a
	P4F-S87	1.6 bcd	11.2 b	217.1 bc	2.1 ab	3.3 a	5.5 a
	P4F-F86	1.3 bc	11.2 b	177.5 ab	1.9 ab	3.7 a	5.1 a
	C-S86	1.4 bc	10.9 b	155.8 ab	2.1 ab	3.5 a	6.1 a
	P4S-F86	1.3 bc	10.0 b	153.4 ab	1.7 ab	2.5 a	5.8 a
	P2F-S87	1.2 ab	10.2 b	131.7 ab	1.1 a	2.5 a	6.4 a
	P2S-F86	1.1 ab	9.6 b	126.9 ab	1.6 ab	3.1 a	5.9 a
	C-F86	1.2 ab	10.1 b	114.2 ab	0.9 a	2.4 a	4.3 a
	C-S87	0.5 a	6.0 a	22.9 a	0.8 a	1.7 a	3.7 a
Smiley Creel	P4S-S86	1.5 d	12.7 d	199.8 c	1.7 a	4.8 d	6.0 a
	P4F-F86	1.2 bc	9.8 abc	126.6 b	1.3 a	3.4 abc	5.0 a
	P2S-S86	1.2 c	11.0 c	125.1 b	1.8 a	3.3 abc	5.5 a
	C-S86	1.2 c	10.6 bc	119.2 b	1.6 a	3.5 abc	5.7 a
	P4S-F86	1.1 bc	10.6 bc	108.2 ab	1.4 a	3.9 bcd	6.2 a
	P4F-S87	1.1 bc	10.7 bc	99.7 ab	1.4 a	4.2 cd	6.0 a
	P2F-S87	1.0 abc	9.1 ab	86.7 ab	1.1 a	2.7 a	6.1 a
	P2F-F86	1.1 abc	9.7 abc	81.9 ab	1.2 a	2.7 a	5.5 a
	P2S-F86	0.8 ab	9.3 abc	65.0 a	1.2 a	2.9 ab	5.5 a
	C-S87	0.8 a	8.7 a	56.5 a	1.0 a	2.7 a	5.5 a
	C-F86	0.8 a	8.1 a	53.6 a	0.7 a	2.5 a	5.5 a

* - refer to Table 2 for HVC-planting date treatment combination definitions.

† - insufficient sample size to include in the statistical analyses. Care should be taken in interpreting the output.

Western Larch

All but a few western larch seedlings regardless of treatment had died before the 1996/1997 re-measurement at Bear Creek and Lost Prairie. Both of these sites were in valley bottoms where frost pockets may have killed the western larch. Western larch seedlings did survive at Smiley Creek, which was on a hillside. There, western larch seedling survival increased on treated plots. On average, survival increased from 11% up to 64% on treated plots (Table 14). Planting season delay did not increase survival among treated plots. Individual tree responses were not significantly better in the treated plots (Table 15). On the other hand, increases in survival led to dramatic increases in plot volume after 11 years, up to 2,478% greater.

Surface Vegetation Cover

Total surface vegetation cover decreased with increasing Pronone herbicide application rates after 10 and 11 years (Table 16). At Gold Creek and Smiley Creek this was due to decreased grass/sedge cover. At Bear Creek and Lost Prairie, the decrease in total cover was due to decreased forb and low shrub cover percentages. This is one explanation for why height growth is still greater in treated plots versus the check plots for the Pronone four pound a.i./acre treatments.

Grass/sedge and total cover on Oust sites showed up to 60% and 47% less cover, respectively, after 11 years. For western larch this has helped increase survival, yet not tree growth.

Table 14. Summary of mean western larch plot responses by HVC-planting date treatment combinations for Smiley Creek after 11 years in the 1985 trial. Significant differences are denoted by different letters.

Site	HVC Treatment Combination*	Survival (%)	Volume (in3)
Smiley Creek	O4S-S86	61.7 de	1854.5 e
	O4F-F86	73.3 e	1314.4 de
	O4F-S87	56.7 de	1289.4 cde
	O2S-S86	48.3 cde	1074.5 cd
	O2S-F86	73.3 e	1017.4 bcd
	O2F-F86	58.3 de	736.1 abcd
	O4S-F86	58.3 de	606.6 abc
	O2F-S87	38.3 cd	377.3 ab
	C-F86	21.7 bc	303.1 a
	C-S86	8.3 ab	222.2 a
	C-S87	5.0 a	50.0 a

* - refer to table 2 for HVC-planting date treatment combination definitions.

Table 15. Summary of mean western larch tree responses by HVC-planting date treatment combinations for Smiley Creek after 11 years in the 1985 trial. Significant differences are denoted by different letters.

Site	HVC Treatment Combination*	DBH (in)	Height (ft)	Volume (in^3)	---- Height Growth (ft/per) ---- P1 (-'88)	P2 ('89-92)	P3 ('93-96)
Smiley Creek	O4F-S87	1.3 c	13.2 a	196.5 a	0.9	2.7	5.5 a
	OS2-S86	1.0 bc	12.2 a	172.1 a	1.6	4.2	5.0 a
	C-S86	1.2 bc	11.5 a	131.3 a	0.9	3	7.4 a
	O4S-S86	1.1 bc	11.7 a	127.4 a	1.8	6.6	7.1 a
	O2F-F86	0.7 abc	9.3 a	94.8 a	----	----	6.5 a
	C-F86	0.9 bc	10.1 a	93.1 a	0.6	2.3	3.9 a
	O4F-F86	0.5 abc	8.3 a	51.3 a	0.8	4.2	7.9 a
	O2F-S87	0.6 abc	9.1 a	50.0 a	----	----	5.9 a
	C-S87	0.6 abc	8.2 a	50.0 a	----	----	5.9 a
	OS4-F86	0.5 ab	8.1 a	22.6 a	1.3	4.2	5.5 a
	O2S-F86	0.0 a	4.4 a	4.1 a	----	----	6.6 a

* - refer to table 2 for HVC-planting date treatment combination definitions.

Table 16. Summary of mean surface vegetation cover percentages by HVC treatment at four sites after 10 to 11 years in the 1985 trial. Significant differences are denoted by different letters.

		Surface Vegetation Cover (%)				
	HVC	Herbaceous		Shrub		
Site	Treatment*	Grass/Sedge	Forb	low	high	Total
Gold Creek	C	11.2 d	20.9	38.2	0.0	70.3 c
	P2S	5.7 c	15.9	44.2	0.0	65.8 bc
	P2F	3.8 bc	21.8	37.8	0.0	63.4 abc
	P4S	2.5 ab	14.6	41.6	0.0	58.7 bc
	P4F	1.6 a	15.1	40.2	0.0	56.9 a
Bear Creek	P2F	30.0 a	44.3	2.8	0.0	77.06 b
	C	24.0 a	38.2	13.7	0.0	75.94 b
	P2S	22.8 a	33.6	15.6	0.0	72.0 b
	P4S	22.0 a	29.5	1.6	0.0	53.06 a
	P4F	20.6 a	20.0	5.3	0.0	45.9 a
Lost Prairie	P2F	55.0 a	44.3	13.9	0.0	113.2 c
	C	41.9 a	37.4	25.3	0.0	104.6 bc
	P2S	50.1 a	26.9	24.8	0.0	101.8 bc
	P4F	44.3 a	27.8	12.9	0.0	84.9 ab
	P4S	47.6 a	15.0	16.6	0.0	79.1 a
Smiley Creek	P2F	21.9 bc	24.9	52.6	23.7	123.0 d
	C	43.9 d	17.9	38.4	17.1	117.4 d
	O4S	24.1 bc	17.3	43.0	13.7	98.0 c
	P2S	25.0 c	14.2	35.4	23.0	97.7 c
	O2F	20.6 bc	26.9	34.1	11.6	93.3 c
	O2S	17.7 b	14.3	35.5	6.3	73.8 b
	P4S	8.8 a	9.7	29.8	22.3	70.6 b
	O4F	19.7 bc	9.2	27.6	6.1	62.6 b
	P4F	7.6 a	11.1	24.9	5.7	49.3 a

* - HVC treatments include Pronone applied at 2 pounds/acre in the fall of 1985 (P2F - Gold Creek) and fall of 1986 (P2F - Bear Creek, Lost Prairie, and Smiley Creek), Pronone applied at 4 pounds/acre in the fall of 1985 (P4F - Gold Creek) and fall of 1986 (P4F - Bear Creek, Lost Prairie, and Smiley Creek), Pronone applied at 2 pounds/acre in the spring of 1985 (P2S), Pronone applied at 4 pounds/acre in the spring of 1986 (P4F), Oust applied at 2 ounces/acre in the spring of 1986 (O2S), Oust applied at 4 ounces/acre in the spring of 1986 (O4S), Oust applied at 2 ounces/acre in the fall of 1986 (O2F), Oust applied at 4 ounces/acre in the fall of 1986 (O4F), and a check plot (C).

Discussion

One-time applications of herbicides to control the amount of competing herbaceous vegetation increased the survival and growth (DBH, height, and volume) of ponderosa pine and lodgepole pine and the survival of western larch on herbaceous plant dominated sites in western Montana. In the initial years after herbaceous vegetation control on the grass-dominated sites, tree seedling survival and growth increased (Petersen 1982, Thamarus and Milner 1989, and McLeod and Mandzak 1990). While vegetation measurements were not reported for the 1981 and 1983 trials, it was evident that better vegetation control (Velpar L vs. Roundup and four pounds. a.i./acre vs. two pounds. a.i./acre) was responsible for increased survival and growth. Better herbaceous vegetation control increased tree survival and growth two years after treatment in the 1985 trial. On sites where grass was not the dominant competitor, such as Boyd Mountain in the 1983 trial and Smiley Creek in the 1985 trial, vegetation control did not increase lodgepole pine survival but did increase tree growth. In fact, at Boyd Mountain, vegetation control decreased survival. Western larch survival was increased with no long-term growth benefits at Smiley Creek. Quick re-invasion by forbs and grasses may have retarded any initial benefits in tree height growth.

The analysis of long term trends revealed that the early gains in tree growth and survival are either maintaining themselves as is the case in the 1981 trial or continuing to increase as is the case in the 1983 and 1985 trials. This is evident in the periodic height growth calculations and/or the height curves. In all trials, height curve differences between the treated and the check plots have decreased over the last five to eight years.

In the 1983 and 1985 trials, trend lines are still diverging but at a slower rate, indicating continued, but decreased growth advantages.

Initial reports indicated substantial vegetation control in treated plots. Current analyses show that grass/sedge cover and total cover continue to be at low levels in the treated plots. As indicated by the results of Zutter and Miller (1998), herbaceous vegetation may have increased following initial herbaceous vegetation control as plants only to be crowded out again or as reported by McLeod and Mandzak (1990), plants may not have re-colonized the open growing space since the time of treatment. Currently, surface vegetation cover is less due to the developing crowns of the trees. With increased survival and growth in the treated plots, the presence of more, larger trees increases shade and decreases light availability to surface vegetation. In the lower light levels, grass and sedge do not compete as well and remain at low densities. This effect supports the ideas presented by Zutter and Miller (1998).

Decreased current vegetation cover in the trials does not imply that trees are growing faster than the check plots. In the 1981 trial, ponderosa pine height growth has been similar between treated and check plots since the trees were approximately 5.0 to 5.5 feet in height. This suggests that the trees may have grown out of a zone of competition with the surface vegetation. Explanations for this phenomenon include a tree's ability to tap into deeper water supplies as well as a better vertical environment over the grass/sedge component that makes light intake and water uptake more efficient.

Another possibility is that inter-tree competition may be occurring. Treated plots through vegetation control, have higher survival rates and bigger trees than the check plots. This results in increased inter-tree competition for site resources. Inter-tree competition may not be present as of yet in the check plots for the opposite reasons. Seedlings also were planted on a six feet by six feet spacing in the 1981 trial. Spacing in the 1983 and 1985 trials is significantly less, as narrow as two feet by two feet spacing. In some instances, seedling height growth advantages have been declining in recent years for the latter two trials, possibly due to inter-tree competition.

Management Concerns and Practical Considerations

A one-time application of herbicide at stand initiation offers silviculturalists a tool for increasing the growth and yield of planted seedlings on herbaceous plant dominated sites in western Montana. Hand scalping alone had no positive effect on long-term tree growth and should not be used alone for competition control on herbaceous plant dominated sites. Height growth increased for up to 14 years from the one-time applications of herbicide in these trials. Further re –measurement of the 1983 and 1985 trials may yield increased height growth for a longer period. This is expressed in the diverging height curves in these trials. Across all trials, the increased height growth supplied seedlings with a two to five year advantage in total height.

Herbicide rate and seedling stock type were found to be the primary concerns in increasing tree survival and DBH, height, and volume growth in these trials. The four pounds a.i./acre treatments did better than the lower rates.

Herbicide application method and season and planting season in relation to the herbicide application season did not significantly affect long term tree and surface vegetation development within treatment plots. In the 1981 trial, the difference between spot and broadcast treatments were negligible. This means that silviculturalists may use the more socially friendly spot treatments instead of large broadcast treatments to entire stands. Spot treatments do have their drawbacks; if the size of the spot is not big enough, re-invasion of herbaceous plants may occur soon after application and restrict seedling growth. In addition, with little effect due to herbicide application and planting season, silviculturalists may apply herbicide in spot treatments a season before planting to alleviate concerns of applying herbicides to already planted seedlings. This would also ensure that seedlings were planted in zones cleared of herbaceous vegetation competition, which may not occur if seedlings are not found when application is applied to already planted seedlings. As seen in the 1983 trial, herbicide treatment applied on already planted seedlings significantly decreased survival.

The possibility of a tree height (5.5 feet) where ponderosa pine grows out of a zone of competition with herbaceous plants has many implications. This suggests that release operations may not work well with ponderosa pine in western Montana if the trees are greater than 5.5 feet tall. In addition, a height of 5.5 feet means that trees are not 'free-to-grow' from surface vegetation at breast height for which local site indices are based. In fact, the 1983 and 1985 trials indicate that lodgepole pine has not reached a 'free-to-grow' status with the surface vegetation for up to a height of 10.0 feet. The height growth differences may affect the use of current site indices in plantations where vegetation is controlled, e. g. site may be over-predicted where herbaceous vegetation control has been applied and site index equations were created from forest conditions following general stand dynamic patterns.

In western Montana, silviculturalists may use one-time applications of herbicide as a means of increasing the productivity of their forest stands, whether seedlings are growing in plantations or in un-managed conditions. With proper stand management through the life of a stand, early advantages of herbaceous vegetation control on conifer survival and growth in western Montana will be maintained throughout the duration of a forest stand. Economic analyses need to be done to determine if the long-term growth benefits will offset initial costs of HVC applications.

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