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Eight-year Tree Growth Following Prescribed Underburning in a Western Montana Douglas-fir/Western Larch Stand

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ABSTRACT

*Eight-year tree growth of western larch (*Larix occidentalis*) and Douglas-fir (*Pseudotsuga menziesii*) was measured following prescribed underburning on burned and control plots in western Montana. Western larch on burned plots had reduced radial growth in the first year following fire but increased growth in the next 7 years. Douglas-fir had similar growth on burned and unburned plots. Growth was not reduced by low levels of crown scorch or cambial injury. Stand basal area growth was less on burned plots due to high fire-caused mortality.*

KEYWORDS: radial increment, basal area increment, prescribed fire, fire effects

Understory burning may be prescribed to accomplish fuel hazard reduction, to manipulate understory vegetation, or to prepare a seedbed for natural regeneration. Impact on the stand may include direct effects such as loss of trees and change in stand structure due to fire-caused mortality, and injury to tree crowns and boles. Possible indirect effects include changes in growth due to tree damage, reduced competition, or changes in nutrient availability.

Little is known about the effects of nonlethal fire treatments on tree growth. Changes in tree growth following fire have been documented in a few cases. Morris and Mowat (1958) documented an increase in diameter and height growth of ponderosa pine (*Pinus ponderosa* Laws.) saplings after fire. Lynch (1959) observed reduced diameter growth in ponderosa pine with high levels of crown scorch. Landsberg and others (1984) found that height and basal area growth of underburned ponderosa pine was significantly less than in adjacent unburned stands. Weber and others (1984) observed a reduction in diameter growth of jack pine (*Pinus banksiana* Lamb.) when litter and organic material on the forest floor was removed.

In 1972 a prescribed burning study designed to quantify effects of underburning in mature western larch (*Larix occidentalis* Nutt.)/Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) forests was begun in the University of Montana's Lubrecht Experimental Forest (Norum 1975). In this study, twenty plots were burned in separate fires in 1973. Norum (1975) reported on fuel consumption, woody shrub consumption, and initial tree mortality. Postfire nutrient cycling (Stark 1977; Stark and Steele 1977) and shrub dynamics (Miller 1977; Stark and Steele 1977) have been previously described. Ryan and others (1988) described fire-caused mortality of Douglas-fir after 8 years.

Although the study had not originally been designed as a tree growth study, it provided an opportunity to gain insight into the effects of fire on growth of Douglas-fir and western larch in this forest type. In 1981 the plots were revisited to assess the impact of the fire treatment on tree growth. This paper examines the effect of burning on both the radial growth of individual trees and the stand basal area growth during the 8-year postburn period.

THE STUDY SITE

The study plots are on a north slope at an elevation of 4,800 ft (1,460 m). The habitat type is *Pseudotsuga menziesii-Vaccinium globulare, Arctostaphylos uva-ursi* phase (Miller 1977; Pfister and others 1977). The stand occupying the site is not vigorous. It is made up primarily of Douglas-fir and western larch, with a small amount of lodgepole pine (*Pinus contorta* Dougl.) and ponderosa pine. Age of overstory trees ranges from 50 to 300 years,

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but average diameter is only about 8.6 inches (22 cm). The area had been selectively logged for mine timbers approximately 50 years before the burn treatment, and an uneven understory of dense Douglas-fir thickets had developed.

METHODS

Thirty-two 13,186-ft^2 (1,225-m^2) plots were inventoried for prefire fuel and stand conditions in 1972 (Norum 1975). Nine of these plots were burned in the spring of 1973 and 11 that fall. The remaining 12 plots served as controls.

All trees with a diameter at breast height of 5 inches (12.7 cm) or more were sampled on a 0.15-acre (0.0625-ha) subplot centered within each treatment plot. Preburn measurements included diameter, height to the nearest 5 feet (1.52 m), and clear bole height. Postburn measurements were taken of scorch height and percentage of crown scorched. In addition, four cambial samples were taken from each tree the following spring and tested to determine if the cambium had been killed. The samples were taken at breast height, one from each quadrant of the tree.

In 1981, 8 years after the treatment, the trees were revisited. Diameter and height were remeasured, and an increment core was taken from each living tree.

Annual radial growth was measured on increment cores using a microprocessor-controlled system with a linear/rotary stage and attached microscope. Annual basal area increment was computed from radial increments and preburn diameter for each year from 1974 to 1981.

No radial growth information was available for dead trees, since increment cores were not taken from them. For purposes of this analysis, we assumed that trees that were dead in 1981 had not grown since 1973.

Because the objectives of the original study did not include examination of tree growth, the precision of the pretreatment measurements of tree height did not allow evaluation of height growth and, consequently, volume growth. Growth analysis was based on the increment cores and was limited to radial and basal area growth.

Radial growth over the 8-year posttreatment period was examined for Douglas-fir and western larch. In order to compare radial growth on burned and unburned plots, it was necessary to account for the effects of tree size and preburn vigor. This was accomplished by dividing each tree's annual radial increment for each of the 8 posttreatment years by its mean annual increment for the 10 years before treatment. This new growth increment, "relative radial increment," is in effect normalized for preburn growth rate. It has no units, and is equal to 1.0 if the growth rate remains constant. Salonius and others (1982) have described this technique as a method of letting each tree serve as its own control.

To test for significant differences in relative radial increment on burned and unburned plots, plot mean relative radial increments were computed for each species for each of the 8 years, and a split plot analysis of variance was employed using years since treatment as a subplot factor. The main plot factor was the burn treatment. A similar analysis was also used to test for significant differences in mean relative radial increment following spring and fall fires. The analysis was weighted using number of observations (live trees) per plot as the weight.

Plot means weighted by number of observations were used in this analysis instead of the individual observations because of the varying number of trees per plot. Because mean values rather than individual observations were used, it was not possible to use analysis of covariance to explore the relationship between the relative radial increment on burned and unburned plots and other factors that might be expected to impact growth, such as level of fire damage. However, correlation analysis was used to explore the relationship between relative radial increment and factors that might impact growth. Percent crown scorch and number of dead cambial samples were used to assess the impact of fire damage on tree growth; postburn plot basal area was used as a measure of competition; and change in plot basal area from fire-caused tree mortality was used as a measure of release from competition.

In a similar split plot analysis, plot basal area growth in burned and unburned plots was compared using years since 1973 as a subplot factor. Correlation between plot basal area growth and post treatment plot basal area and change in plot basal area was examined to assess the impact of competition and release from competition on stand basal area growth.

Projections of stand development on each of the 32 plots were obtained from the Stand Prognosis Model (Wykoff and others 1982) using the 1981 tree inventory and the 8-year posttreatment increment to calibrate the model to the stands. These projections were used to speculate on long-term impacts of the prescribed fire treatment on stand development.

RESULTS AND DISCUSSION

As expected, t-tests showed no significant differences at the 95 percent confidence level in pretreatment (1972) diameter, height, number of trees, or plot basal area between burned and unburned plots (table 1), indicating that the plots did not differ in stand characteristics. Preburn growth increment could not be compared because data were not available on trees that had died. To compare preburn growth, the assumption would have to be made that dead trees had similar preburn growth increments to live trees. This assumption seemed too extreme.

In 1981, diameter, mortality since 1972, and change in plot basal area since 1972 were significantly larger on burned plots than on unburned plots, while number of trees and plot basal area were significantly smaller, indicating that the fire treatment selectively killed smaller trees.

Table 1—Stand descriptors on burned and unburned plots

Descriptor	Burned plots (*n*=20) $\bar{x}$	Burned plots (*n*=20) *s*	Unburned plots (*n*=12) $\bar{x}$	Unburned plots (*n*=12) *s*	*p* value for difference between burned and unburned means
1972 diameter (cm)	22.3	2.6	21.1	2.0	0.18
1972 height (m)	15.5	1.4	15.30	1.0	.76
1972 number of trees per hectare	359	96	412	63	.10
1972 stand basal area (m²/ha)	13.3	4.1	13.4	1.2	.90
1981 diameter (cm)	24.5	3.9	21.8	2.6	.05
1981 height (m)	16.4	2.0	15.8	1.1	.30
1981 number of trees per hectare	229	96	369	77	.0002
1981 stand basal area (m²/ha)	9.6	4.1	12.6	1.3	.006
1972-81 mortality (percent)	37.4	18.2	10.7	9.9	.0001
1972-81 decrease in stand basal area (m²/ha)	3.6	2.3	.8	.7	.0001

Radial Increment

Relative radial increments of Douglas-fir and western larch on burned and unburned plots are shown in figures 1 and 2. The increments are quite variable from year to year, but this variability follows a similar pattern on burned and unburned plots and for the two species, and can probably be attributed to yearly weather variations. Relative radial increment on burned plots was less than on unburned plots in the first year for western larch, and almost equal for Douglas-fir. In every subsequent year relative radial increment was greater on burned than on unburned plots for both species, and the difference increased for the first 4 years. In western larch, average relative radial increment was 60 to 80 percent greater on the burned plots than on the unburned plots from the fourth through the eighth year following treatment. In Douglas-fir the relative radial increment was only 10 to 30 percent greater on burned plots than on unburned plots. Douglas-fir and western larch were codominant in the stand, but western larch was more successful in responding to the fire treatment. This same relationship was evident in the unadjusted radial growth increments (table 2).

Analysis of variance showed that the difference in relative radial increment between treatments was significant ($p = 0.04$) for western larch. Years since treatment was also significantly related to growth ($p = 0.0001$), which simply confirms the observation that growth differed from year to year. The interaction of treatment and years since treatment was highly significant ($p = 0.0007$), showing that the trend over the 8-year period was different on burned and unburned plots.

Differences between treatments and treatment-by-year interaction were not statistically significant ($p = 0.21$) for Douglas-fir. Douglas-fir showed the same general response to treatment as western larch, but at a smaller, statistically insignificant magnitude. The growth of Douglas-fir was not significantly increased or reduced by fire.

No significant difference in relative radial increment was found between spring burn and fall burn treatments for either species.

Fire damage was quite light on surviving trees. Crown scorch ranged from 0 to 80 percent but averaged only 5 percent. Most surviving trees had only one or no dead cambial sample out of the four taken. Percent crown

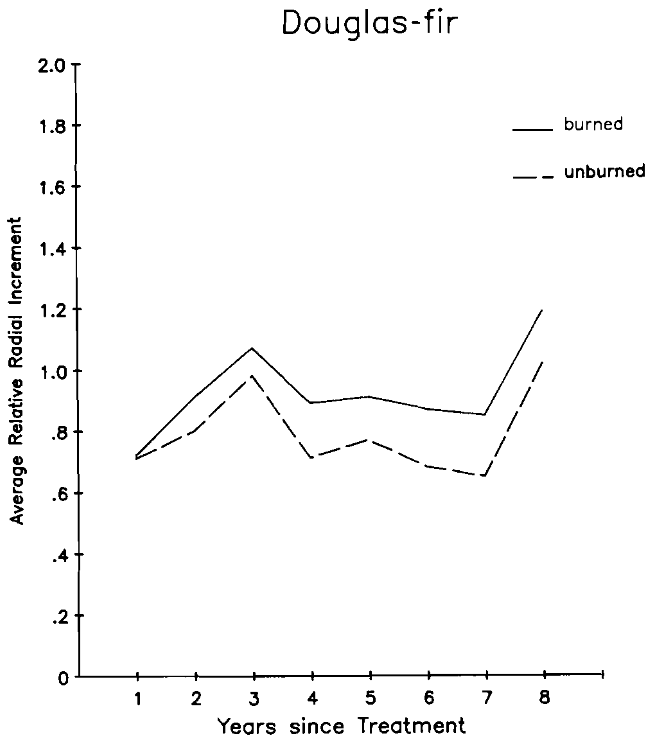

Figure 1—Mean annual relative radial growth of Douglas-fir trees on burned and unburned plots.

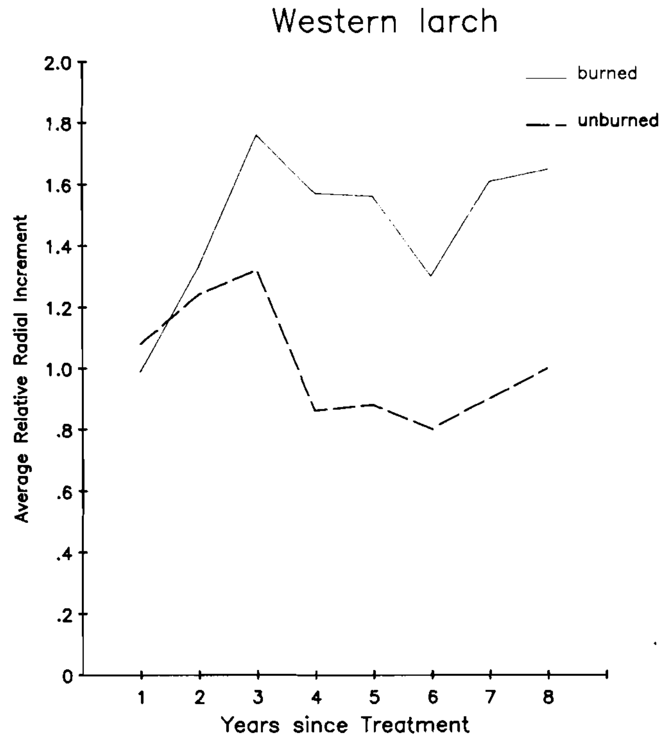

Figure 2—Mean annual relative radial growth of western larch trees on burned and unburned plots.

Table 2—Average unadjusted radial growth increment (cm) of trees on burned and unburned plots for the first 8 years after treatment

	Western larch		Douglas-fir	
Year	**Burned**	**Unburned**	**Burned**	**Unburned**
1	0.114	0.121	0.053	0.054
2	.150	.136	.066	.063
3	.193	.139	.075	.079
4	.175	.091	.061	.054
5	.173	.093	.062	.059
6	.143	.087	.060	.052
7	.171	.093	.061	.049
8	.181	.106	.082	.076

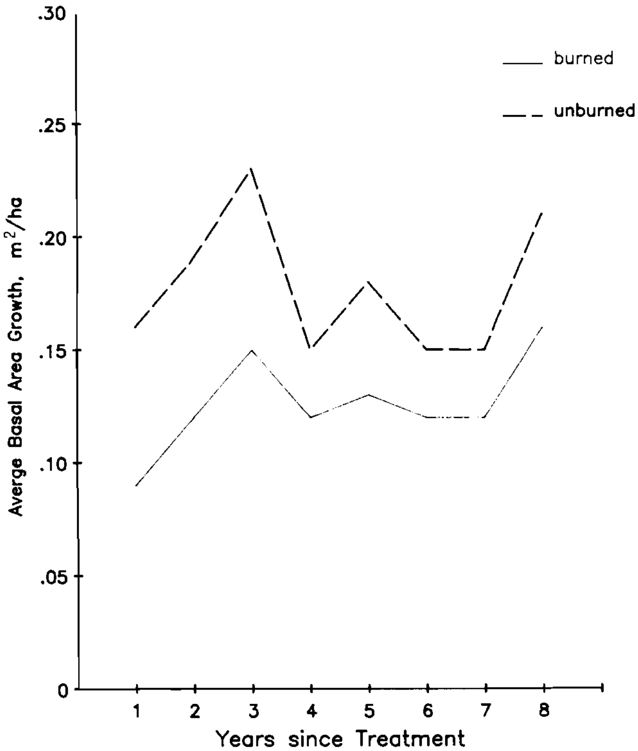

Figure 3—Average annual basal area growth on burned and unburned plots (m^2/ha).

scorch and relative radial growth were not significantly correlated for any of the 8 posttreatment years for either species. Variable but mostly positive correlations were found between number of dead cambial samples and relative radial increments for all 8 years. Although some trees were killed by the fire treatment, growth of surviving trees was not reduced by fire damage. Postburn plot basal area was not correlated with relative radial increment of Douglas-fir, but it was significantly negatively correlated with the increment of western larch. Similarly, decrease in plot basal area due to fire- caused mortality was not significantly correlated with the relative radial increment of Douglas-fir, but was positively correlated with the growth increment of western larch. This suggests that the difference between treatments may be due to release from competition, and that the Douglas-fir was less effective in responding to release than the western larch.

Plot Basal Area Increment

Plot basal area increment was smaller on burned plots than on unburned plots for each year from 1974 to 1981 (fig. 3). Eight-year plot basal area increment was almost 1.5 times greater on unburned plots than on burned plots. Analysis of variance showed this difference to be highly significant (p = 0 .002). Correlation analysis showed that plot basal area increment was positively correlated with plot basal area and trees per hectare, and negatively correlated with the fire-caused change in basal area.

Stand Prognosis Model Projections

Projections of stand development obtained from the Stand Prognosis Model showed that projected annual volume growth was less, but not significantly less, on burned plots than on unburned plots. This difference decreased over the 100-year projection period. On the other hand, projected annual mortality was greater on unburned plots, and this difference was significant and increased over the projection period. Near the end of the 100-year projection period, projected total volume (board feet per acre) on burned plots surpassed that on unburned plots.

SUMMARY AND CONCLUSIONS

Prescribed burning in these stands resulted in an increase in individual tree relative radial increment in western larch. By the second year after treatment, radial growth on burned plots surpassed that on unburned plots, and it remained greater throughout the 8-year study period. Relative radial increments of Douglas-fir were not different on burned plots than on unburned plots.

Although 8-year individual tree growth was not reduced by fire, stand growth was reduced due to high tree mortality in burned plots. Trees killed by the fire were smaller with proportionately less merchantable volume than surviving trees. Projected stand growth from the Stand Prognosis Model was less in burned plots than in unburned plots. However, the projected growth was distributed among fewer, larger trees, and less of it was lost in subsequent projected mortality.

These stands were in poor condition, as is demonstrated by the slow growth and by the high mortality and declining basal area even in unburned stands. Although there was a marked increase in radial growth of western larch in burned plots, it continued to be slow (around 1 mm/yr). The response to release may not be enough to suggest that thinning stands such as these with fire is a silviculturally effective option. More important is the finding that individual tree growth was not reduced by the fire treatment, even in trees that had some fire damage. Fire can apparently be successfully used to reduce fuels or for other management purposes without negatively impacting radial growth on surviving trees, in this type of stand. More work needs to be done to find out if these results are more widely applicable.

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