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Occurrence of Conifer Seedlings and Their Microenvironments on Disturbed Sites in Central Idaho

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RESEARCH SUMMARY

Natural regeneration of six conifer species was surveyed on three central Idaho habitat types (h.t.): Douglas-fir/white spirea h.t. (*Pseudotsuga menziesii*/*Spiraea betulifolia* h.t.), grand fir/mountain maple h.t. (*Abies grandis*/*Acer glabrum* h.t.), and grand fir/blue huckleberry h.t. (*Abies grandis*/*Vaccinium globulare* h.t.). The species sampled were lodgepole pine (*Pinus contorta*), western larch (*Larix occidentalis*), ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Pseudotsuga menziesii*), Engelmann spruce (*Picea engelmannii*), and grand fir (*Abies grandis*). Seedling occurrence was related to seedbed, amount and kind of shade cover, site preparation method (no site preparation, broadcast burning, light and heavy scarification), and silvicultural method (clearcutting, seed-tree cutting, shelterwood cutting, selection cutting). An "index of regeneration efficiency" was developed to indicate possible beneficial and detrimental effects of seedbeds or covers for each seedling species. The indexes and percentage occurrences of seedlings are used to provide recommendations for silvicultural and site preparation treatments that can be used to obtain desired natural regeneration in the three habitat types.

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Occurrence of Conifer Seedlings and Their Microenvironments on Disturbed Sites in Central Idaho

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INTRODUCTION

Successful forest management requires prompt tree regeneration following timber harvesting. With the increase in planting costs, many forest managers have turned to natural regeneration to restock stands (Gashwiler 1970). Natural regeneration of stands to adequate stocking levels is often slow (Fiedler and others 1985; Minore and Dubrasich 1981), and many studies have investigated the seedbed requirements for various conifer species. Few studies, however, have characterized the seedling micro-environment in terms of both seedbed and seedbed cover.

Seed germination and establishment depends on critical environmental conditions. A microenvironment that provides a seed with the requirements for germination and establishment was defined by Harper (1977) as a "safe site." The absence of a particular species from an area may be due either to insufficient seed dispersed to the site or to a lack of safe sites. Silviculturists use several methods to manipulate the amount of available conifer seed, but little is known about the required safe sites for that seed. Once identified, site preparations after timber harvesting can be manipulated to provide as many safe sites as possible for a desired conifer species. This study was undertaken to define safe sites for coniferous trees in west central Idaho.

METHODS

The study was conducted in the Douglas-fir (*Pseudotsuga menziesii* var. *glauca*) and grand fir (*Abies grandis*) forests on the Boise and Payette National Forests in west-central Idaho. In the Douglas-fir forests, Douglas-fir is the dominant species often growing with ponderosa pine (*Pinus ponderosa*) (Steele and others 1981). Grand fir is the dominant conifer in grand fir forests, often growing with ponderosa pine, lodgepole pine (*Pinus contorta*), Douglas-fir, Engelmann spruce (*Picea engelmannii*), and western larch (*Larix occidentalis*). Within these forests, three habitat types based on potential climax vegetation were sampled: Douglas-fir/white spirea (*Pseudotsuga menziesii*/*Spiraea betulifolia*) habitat type (h.t.), grand fir/mountain maple (*Abies grandis*/*Acer glabrum*) h.t., and grand fir/blue huckleberry (*Abies grandis*/*Vaccinium globulare*) h.t. (Steele and others 1981). The Douglas-fir habitat types are normally drier and warmer than the grand fir habitat types. The grand fir/mountain maple h.t. occurs in environments in the grand fir zone that are warmer than the grand fir/blue huckleberry h.t. environment.

Sample sites were located in the study area "subjectively but without preconceived bias" as described by Mueller-Dombois and Ellenberg (1974). Areas identified as Douglas-fir/white spirea, grand fir/mountain maple, and grand fir/blue huckleberry h.t. were reconnoitered to identify stands with some type of disturbance. Sample points were selected to represent the range of silvicultural methods and site preparation combinations available. The sample points were in representative portions of the stands in areas with uniform treatments. The silvicultural methods sampled included clearcuts, shelterwood cuts, seed-tree cuts, and group selection cuts. Site preparations included none (no slash disposal and little harvesting impact), broadcast burning, and two types of scarification—light scarification (from slash disposal or harvesting activities) and heavy scarification (contour terracing). Only sites with 5-year-old or older disturbances were included. At each sampling point, five 108-ft² (10-m²) circular plots were located with one at the center (designated CENTER) and four peripheral (designated LEFT, RIGHT, UP, DOWN) 22.5 ft (6.9 m) from the middle of plot CENTER. Plots UP and DOWN were perpendicular to the contour upslope and downslope of CENTER respectively. Plots RIGHT and LEFT were on the contour to the right and left of CENTER. In using this sampling method, I assumed that safe sites were randomly dispersed within the uniform site treatment. All plots will be referred to as seedling plots. I treated each seedling plot as a separate plot for summarization.

For each seedling plot, I recorded the percentage of the plot covered by various soil surface conditions (seedbeds) and percentage coverages of vegetation and debris. Information on all conifer seedlings present included species, seedbed, and species of or kind of overhanging (influential) vegetation or debris. Seedbed categories were litter-covered mineral soil, bare mineral soil, moss mats, residual duff, and rotten wood. Rocks and stumps were also recorded as seedbeds.

Seedlings 3 years old or older, but younger than the disturbance, were recorded. Seedlings were clipped and aged in the laboratory, or when possible, were aged on site by counting bud scars or nodes. Each individual seedling or cluster of seedlings (cache) was recorded as an occurrence. For each sample site I recorded aspect, slope, and elevation. The dates (year) of timber harvesting and site disturbance were estimated from management records, plantation signs, tree growth release indications from increment borings, and cross sections of machine scars that occurred during timber harvesting. All sampling

occurred during the summers of 1984 and 1985. A total of 56 sites (280 seedling plots) were sampled in the Douglas-fir/white spirea h.t., 70 sites (350 seedling plots) in the grand fir/mountain maple h.t., and 24 sites (120 seedling plots) in the grand fir/blue huckleberry h.t.

The data from this study were not well suited to statistical analysis because the number of seedlings sampled of each species inadequately represented all the various silvicultural method-site preparation combinations, and the distribution of sampling plots throughout the combinations was not uniform. Rather, this was intended as a retrospective study of the effects of the various treatment combinations on the occurrence of natural tree regeneration.

I summarized the data by harvest-regeneration treatments, site preparation treatments, and amount of shade cover. For these summaries, the results are expressed as percentages based on the average number of seedlings for each treatment. Averages resulted from dividing the number of seedlings in a treatment by the number of treatments. Average number of years to establishment after disturbance were obtained by subtracting the seedling age from the disturbance age and averaging the results for each species in a habitat type. The average is a weighted average based on the number of seedlings of each species.

To evaluate the effect of the safe site components (seedbed or cover), an "index of regeneration efficiency" (RE) was calculated. The RE values were obtained by dividing the percentage occurrence of seedlings in a safe site component by the percentage occurrence of the safe site component. Percentage occurrence of seedlings is the percentage of seedlings that were found on or under a safe site component based on the total number of seedlings. Percentage occurrence of a safe site component was obtained by multiplying constancy of the safe site component (percentage occurrence over all plots) by average cover of each component. The values were totaled for all covers or seedbeds, and the totals were used to obtain percentage occurrence of a particular safe site component. The percentage occurrence of seedlings used to obtain RE values is not the same as the percentages used for the previous summaries. This is because average number of seedlings per safe site component could not be obtained since the area occupied by each component varied from plot to plot. For this reason, RE values were used for these summaries. A regeneration efficiency of 1.00 indicates that the seedlings occurred in a particular safe site component in proportion to the occurrence of the component. Indexes greater than 1.00 indicate that seedling occurrence was much higher on a particular component than the occurrence of the component, and indexes less than 1.00 indicate that seedling occurrence is much lower than the occurrence of the component. Using this index, possible beneficial or detrimental effects of the safe site can be indicated. The following subjective categories and classes were assigned to RE values:

- Class 1: 0 to 0.25, very inefficient
- Class 2: 0.26 to 0.75, inefficient
- Class 3: 0.76 to 1.50, efficient
- Class 4: 1.51 to 3.00, moderately efficient
- Class 5: 3.01 and greater, very efficient.

RESULTS AND DISCUSSION

Approximately 370 seedlings per acre (920 per ha) were found in the Douglas-fir/white spirea h.t. (table 1). Regeneration was greater in the grand fir forests with 480 seedlings per acre (1,190 per ha) in both grand fir/mountain maple and grand fir/blue huckleberry h.t. Of the seedlings in the Douglas-fir/white spirea h.t., 64 percent were Douglas-fir, while ponderosa pine made up 24 percent of the total. In the grand fir forests, grand fir accounted for 49 percent in the mountain maple h.t. and 50 percent in the blue huckleberry h.t. Douglas-fir was also common. The average number of years to establishment after disturbance varied by species and by habitat type (table 1). Overall, seedling establishment took longest in the cool grand fir/blue huckleberry h.t. and was shortest in the moderate grand fir/mountain maple h.t.

Seedbeds

The most common seedbed safe site component in all three habitat types was litter-covered mineral soil followed by bare mineral soil and moss mats (table 2). Rocks or stumps, rotten wood, and residual duff were less common. Residual duff was amassments of organic material that had accumulated under the predisturbance stand and had remained intact following the disturbance. Litter-covered scarified soils were mineral soils that had been exposed during the disturbance and were accumulating litter. Moss mats were composed primarily of juniper haircap moss (*Polytrichum juniperinum*), which produces loose, erect stems and was usually found on scarified soils.

In many cases RE values were very efficient or moderately efficient for seedlings on residual duff, rotten wood, or moss mats. The RE values were mostly inefficient and efficient for seedlings on litter-covered and bare mineral soil. In other areas, investigators have found that seedlings often occurred on seedbeds of rotten wood or duff. Knapp and Smith (1982), in the Medicine Bow Mountains of southeastern Wyoming, and Day (1964), in the Crownsnest Forest of southwest Alberta, found that Engelmann spruce seedlings occurred on rotten wood and moss mats in a larger proportion than would be expected from the area occupied by the seedbed (RE value greater than 1.00). Day (1964) also found that "mineral soil with incorporated humus" and "fermented and humified humus" were very efficient seedbeds for Engelmann spruce. Harvey (1982) states that rotten wood and humus provide a more favorable seedbed than does mineral soil because mineral soil gains and loses nutrients rapidly, has low nutrient and moisture holding capacities, and changes temperature quickly, whereas humus and decayed wood gain and lose nutrients slowly, have high nutrient and water-holding capacity, and change temperature slowly. Soil organic matter such as humus and decayed wood also increase the ability of the soil to support mycorrhizae, particularly on dry slopes (Harvey and others 1976).

Table 1—Average number of tree seedlings per acre, percentage occurrence per acre, and average number of years to establishment after disturbance for tree seedlings in the Douglas-fir/white spirea, grand fir/mountain maple, and grand fir/blue huckleberry habitat types

Tree species	Average number of seedlings per acre	Percent of total sample	Average number of years to establishment after disturbance	Range of years to establishment
Douglas-fir/White Spirea Habitat Type				
Lodgepole pine	44	12	3	¹ 0 - 14
Ponderosa pine	87	24	5	0 - 18
Douglas-fir	238	64	9	0 - 25
Total	369	100	² 7	
Grand Fir/Mountain Maple Habitat Type				
Lodgepole pine	5	1	2	0 - 5
Western larch	21	4	1	0 - 14
Ponderosa pine	51	11	5	0 - 13
Douglas-fir	144	30	7	0 - 46
Engelmann spruce	25	5	3	0 - 6
Grand fir	234	49	7	0 - 30
Total	480	100	6	
Grand Fir/Blue Huckleberry Habitat Type				
Lodgepole pine	29	6	9	2 - 20
Ponderosa pine	38	8	11	3 - 19
Douglas-fir	90	19	8	0 - 19
Engelmann spruce	81	17	7	0 - 22
Grand fir	237	50	9	0 - 29
Total	475	100	9	

¹0 years to establishment means that seedlings established in the same year that disturbance took place.

²Weighted average.

Table 2—Percentage occurrence of natural tree seedlings by seedbed with regeneration efficiencies (RE)¹ classes of seedbeds for Douglas-fir/white spirea, grand fir/mountain maple, and grand fir/blue huckleberry habitat types

Species	Scarified soil										Rocks or stumps	
	Litter-cover		Bare		Moss mat		Rotten wood		Residual duff			
	Pct	RE class ²	Pct	RE class	Pct	RE class	Pct	RE class	Pct	RE class	Pct	RE class
Douglas-fir/White Spirea Habitat Type												
Lodgepole pine	64	3	36	3	—	—	—	—	—	—	—	—
Ponderosa pine	38	2	47	4	13	5	2	4	—	—	—	—
Douglas-fir	63	3	29	3	6	4	1	3	1	2	—	—
Seedbed occurrence ³	63		29		2		<1		4		<1	
Grand Fir/Mountain Maple Habitat Type												
Lodgepole pine	25	2	25	3	56	5	—	—	—	—	—	—
Western larch	17	1	49	4	28	5	6	5	—	—	—	—
Ponderosa pine	69	3	13	3	16	4	2	3	—	—	—	—
Douglas-fir	52	3	25	3	21	4	1	2	1	4	—	—
Engelmann spruce	50	2	18	3	27	5	5	4	—	—	—	—
Grand fir	65	3	14	2	18	4	2	3	1	5	—	—
Seedbed occurrence	67		22		8		2		<1		<1	
Grand Fir/Blue Huckleberry Habitat Type												
Lodgepole pine	30	2	50	5	20	4	—	—	—	—	—	—
Ponderosa pine	31	2	38	4	23	4	8	4	—	—	—	—
Douglas-fir	59	3	19	3	16	3	6	4	—	—	—	—
Engelmann spruce	46	2	3	1	45	5	3	3	3	4	—	—
Grand fir	63	3	10	2	10	3	15	5	2	3	—	—
Seedbed occurrence	67		15		13		2		2		<1	

¹Regeneration efficiency is the percentage occurrence of the seedling species divided by the percentage occurrence of the safe site component.

²Class 1: 0 to 0.25, very inefficient; class 2: 0.26 to 0.75, inefficient; class 3: 0.76 to 1.50, efficient; class 4: 1.51 to 3.00, moderately efficient; class 5: 3.01 and greater, very efficient.

³Seedbed occurrence is the percentage occurrence of a seedbed over all microplots.

Cover

The second component of safe sites is the influence of vegetation and debris. The occurrence of different seedling species varied according to the amount of shrub canopy cover (shade) over the seedling plot (table 3). However, the trends for most species were similar between habitat types. Most seedling species occurred in moderate (33 to 66 percent shrub canopy cover) and heavy (67 to 100 percent) shade. This included even the shade-intolerant species ponderosa pine and lodgepole pine (as defined by Daniel and others 1979; Minore 1979), which were found predominately in moderate shade in all three habitat types. Douglas-fir was found most often under heavy shade. Engelmann spruce, which is rated as less shade tolerant than Douglas-fir (Minore 1979), was found most often under heavy shade in grand fir/mountain maple h.t. and under light (0 to 33 percent) shade in the grand fir/blue huckleberry h.t.

Table 3—Occurrence of tree seedlings (percentage) by shrub canopy cover for Douglas-fir/white spirea, grand fir/mountain maple, and grand fir/blue huckleberry habitat types

Occurrence by species	Shrub canopy cover		
	Light (0-33%)	Moderate (33-66%)	Heavy (66-100%)
Douglas-fir/White Spirea Habitat Type			
Percentage of microplots	42	36	22
Lodgepole pine	16	44	40
Ponderosa pine	17	42	41
Douglas-fir	31	32	37
Grand Fir/Mountain Maple Habitat Type			
Number of microplots	34	26	40
Lodgepole pine	20	80	—
Western larch	34	58	8
Ponderosa pine	27	49	24
Douglas-fir	23	14	63
Engelmann spruce	15	20	65
Grand fir	32	38	30
Grand Fir/Blue Huckleberry Habitat Type			
Number of microplots	28	35	37
Lodgepole pine	12	60	28
Ponderosa pine	28	45	27
Douglas-fir	35	22	43
Engelmann spruce	46	17	37
Grand fir	26	25	49

While the large occurrence of shade-tolerant species on moderately or heavily shaded plots would be expected, the high occurrence of shade-intolerant species on such plots appears incongruent. McConkie and Mowat (1936) found that germination of ponderosa pine in central Idaho was higher under heavy shade, though the death rate of the first-year germinants was also higher under heavy shade than under more intermediate shade or no shade. The net effect at the end of the year was an increase in seedling occurrence with increasing shade. This relationship may hold for many years. The presence of a shade-intolerant species under heavy shade may indicate a safe site—that is, a favorable microenvironment for germination and establishment. However, other safe sites such as a safe site with light shade may provide for faster seedling growth.

Several safe site covers were encountered for the various seedlings throughout the three habitat types (table 4). While the cover RE values often varied considerably between habitat types for the same conifer seedling species, in some cases the RE values for cover species were consistently high or low across habitat types. Notably, thimbleberry (*Rubus parviflorus*) was very efficient for lodgepole pine, ponderosa pine, Douglas-fir, Engelmann spruce, and grand fir in the grand fir/blue huckleberry h.t. and for ponderosa pine and Engelmann spruce in the grand fir/mountain maple h.t. Cover of forbs and grasses and sedges was consistently either very inefficient or inefficient for all species in all three habitat types. The use of a "cover species" and the associated RE value does not intend to imply that a particular cover precludes or is required to obtain a particular seedling. In many cases, the relationship between the cover species and the seedling species may be coincidental; the seedling and the cover species may merely have established in the same location at the same time. On the other hand, a very high or very low RE value may indicate a relationship. The particular cover species may be established in a microenvironment that is favorable or unfavorable to a particular conifer species, and therefore can be used as an indicator of a suitable or unsuitable microenvironment. An example of such a species is Sitka alder (*Alnus sinuata*), which is a very efficient cover species for Engelmann spruce in the grand fir/mountain maple h.t. Sitka alder often occurs in wetter portions of the grand fir/mountain maple h.t., indicating areas that are well suited to Engelmann spruce (Steele and Geier-Hayes 1985). Other cover species may by their characteristics affect the safe site. On one hand, an allelopathic species may preclude the formation of a safe site. On the other hand, a species that supports nitrogen-fixing organisms may create a safe site by providing a favorable rooting environment.

Table 4—Regeneration efficiency (RE)¹ classes for shrub canopies and other microsites for Douglas-fir/white spirea, grand fir/mountain maple, and grand fir/blue huckleberry habitat types

Type of cover	Constancy	Area occupied	Species					
			Lodgepole pine	Western larch	Ponderosa pine	Douglas-fir	Engelmann spruce	Grand fir
			----- Percent -----					
Douglas-fir/White Spirea Habitat Type								
None	—	—	² 68	—	41	5	—	—
Grasses and sedges	100	20	—	—	³ 1	1	—	—
Forbs	100	18	—	—	—	2	—	—
<i>Spiraea betulifolia</i>	70	17	4	—	3	4	—	—
<i>Pinus ponderosa</i>	34	11	—	—	3	3	—	—
<i>Prunus</i> spp.	39	7	—	—	—	1	—	—
Slash	57	5	—	—	3	4	—	—
<i>Symphoricarpos</i> spp.	31	4	—	—	3	2	—	—
<i>Amelanchier alnifolia</i>	23	4	—	—	3	3	—	—
<i>Berberis repens</i>	40	3	—	—	—	2	—	—
<i>Ribes</i> spp.	10	2	—	—	—	2	—	—
<i>Populus tremuloides</i>	4	1	—	—	—	2	—	—
<i>Ceanothus velutinus</i>	28	1	—	—	4	4	—	—
<i>Salix scouleriana</i>	7	1	—	—	3	3	—	—
<i>Pseudotsuga menziesii</i>	6	1	—	—	3	—	—	—
<i>Purshia tridentata</i>	5	<1	—	—	4	4	—	—
<i>Pinus contorta</i>	3	<1	5	—	—	3	—	—
<i>Artemisia tridentata</i>	2	<1	—	—	5	—	—	—
<i>Rosa</i> spp.	10	<1	—	—	—	3	—	—
<i>Rubus parviflorus</i>	1	<1	—	—	—	—	—	—
<i>Lonicera utahensis</i>	2	<1	—	—	—	—	—	—
<i>Sorbus scopulina</i>	1	<1	—	—	—	—	—	—
<i>Acer glabrum</i>	2	<1	—	—	—	—	—	—
<i>Physocarpus malvaceus</i>	<1	<1	—	—	—	—	—	—
<i>Sambucus racemosa</i>	1	<1	—	—	—	—	—	—
Grand Fir/Mountain Maple Habitat Type								
None	—	—	25	24	27	14	18	19
Forbs	97	17	—	—	1	2	2	2
<i>Rubus parviflorus</i>	27	15	—	3	5	3	5	2
<i>Ceanothus velutinus</i>	35	13	—	2	2	3	—	3
Grasses and sedges	66	9	—	—	—	—	—	1
<i>Salix scouleriana</i>	32	8	—	—	2	3	2	3
Slash	76	6	—	—	—	3	2	2
<i>Pinus ponderosa</i>	24	6	—	—	3	2	—	2
<i>Ribes</i> spp.	46	5	—	5	4	3	—	3
<i>Vaccinium globulare</i>	21	4	—	5	4	4	3	4
<i>Physocarpus malvaceus</i>	24	4	—	—	—	1	4	4
<i>Abies grandis</i>	12	3	5	—	2	1	—	2
<i>Alnus sinuata</i>	6	3	—	—	—	—	5	2
<i>Lonicera utahensis</i>	26	3	5	5	3	3	—	3
<i>Acer glabrum</i>	18	2	—	—	—	4	—	5
<i>Spiraea betulifolia</i>	30	2	—	—	—	2	—	2
<i>Pseudotsuga menziesii</i>	15	2	—	—	—	2	—	3
<i>Prunus</i> spp.	8	2	—	—	—	3	—	2
<i>Symphoricarpos</i> spp.	13	1	—	—	—	3	—	—
<i>Pachistima myrsinites</i>	3	<1	—	—	—	4	—	—
<i>Sorbus scopulina</i>	5	<1	—	—	—	—	5	—
<i>Amelanchier alnifolia</i>	6	<1	—	—	—	—	—	—
<i>Rosa</i> spp.	25	<1	—	—	5	3	—	—
<i>Larix occidentalis</i>	<1	<1	—	—	—	4	—	—
<i>Shepherdia canadensis</i>	2	<1	—	—	—	—	—	5
<i>Picea engelmannii</i>	2	<1	—	—	—	—	—	—
<i>Populus tremuloides</i>	1	<1	—	—	—	—	—	—
<i>Artemisia tridentata</i>	1	<1	—	—	5	—	—	—
<i>Clematis columbiana</i>	2	<1	—	—	—	5	—	—
<i>Sambucus racemosa</i>	3	<1	—	—	—	—	—	—
<i>Berberis repens</i>	3	<1	—	—	—	—	—	—

(con.)

Table 4 (Con.)

Type of cover	Constancy	Area occupied	Species					
			Lodgepole pine	Western larch	Ponderosa pine	Douglas-fir	Engelmann spruce	Grand fir
	----- Percent -----							
	Grand Fir/Blue Huckleberry Habitat Type							
None	—	—	10	—	31	13	11	7
Grasses	90	17	—	—	2	—	—	1
Forbs	96	13	—	—	—	2	2	1
<i>Vaccinium globulare</i>	52	13	4	—	4	4	4	4
<i>Pinus ponderosa</i>	34	10	—	—	—	2	2	4
<i>Salix scouleriana</i>	36	9	—	—	—	3	4	4
<i>Lonicera utahensis</i>	42	6	5	—	—	2	4	1
<i>Alnus sinuata</i>	10	5	—	—	—	—	—	2
<i>Ceanothus velutinus</i>	13	5	—	—	—	2	—	3
<i>Ribes</i> spp.	50	5	—	—	4	3	2	3
<i>Abies grandis</i>	10	4	—	—	—	—	—	—
Slash	62	3	—	—	—	—	—	4
<i>Spiraea betulifolia</i>	38	3	5	—	—	4	3	3
<i>Pinus contorta</i>	8	2	—	—	—	—	—	—
<i>Larix occidentalis</i>	4	1	—	—	—	—	—	—
<i>Shepherdia canadensis</i>	3	<1	—	—	—	—	—	—
<i>Pseudotsuga menziesii</i>	10	1	—	—	—	—	—	—
<i>Rubus parviflorus</i>	14	<1	5	—	5	5	5	5
<i>Sambucus racemosa</i>	4	<1	—	—	—	—	—	—
<i>Pachistima myrsinites</i>	8	<1	—	—	—	5	—	—
<i>Picea engelmannii</i>	4	<1	—	—	—	—	5	—
<i>Rosa</i> spp.	16	<1	—	—	—	—	—	—
<i>Symphoricarpos oreophilus</i>	1	<1	—	—	—	—	—	—
<i>Amelanchier alnifolia</i>	3	<1	—	—	5	—	—	—
<i>Physocarpus malvaceus</i>	1	<1	—	—	—	—	—	—
<i>Sorbus scopulina</i>	2	<1	—	—	—	—	—	—
<i>Prunus</i> spp.	2	<1	—	—	—	—	—	—

¹Regeneration efficiency is the percentage occurrence of the seedling species divided by the percentage occurrence of the safe site component.

²During sampling, no estimate of "none" type of cover was made for each plot. Therefore, this value is the percentage of seedlings that had no cover. The remaining percentage is represented in the RE value for the type of cover under which the seedling was found.

³Class 1: 0 to 0.25, very efficient; class 2: 0.26 to 0.75, inefficient; class 3: 0.76 to 1.50, efficient; class 4: 1.51 to 3.00, moderately efficient; class 5: 3.01 and greater, very efficient.

Site Treatment

The cover species and seedbeds that remain on the site after timber harvesting are influenced by the type of site preparation used to dispose of slash or prepare for artificial regeneration. For most species in most habitat types, scarification resulted in the largest proportion of seedlings (table 5). Moss mats, which were moderately efficient or very efficient seedbeds for most species, usually occurred on sites that had been scarified and occasionally on sites that had been broadcast burned. Broadcast burning resulted in the largest proportion of Douglas-fir seedlings in both the Douglas-fir/white spirea and grand fir/blue huckleberry h.t.

Table 5—Occurrence of tree seedlings (percentage) by site preparation methods for Douglas-fir/white spirea, grand fir/mountain maple, and grand fir/blue huckleberry habitat types

Species	No preparation	Broadcast burn	Scarification	
			Light	Heavy
Douglas-fir/White Spirea Habitat Type				
Percentage of microplots	6	15	50	29
Lodgepole pine	—	41	59	—
Ponderosa pine	19	22	44	15
Douglas-fir	8	58	27	7
Grand Fir/Mountain Maple Habitat Type				
Number of microplots	15	7	55	23
Lodgepole pine	—	—	100	—
Western larch	—	—	87	13
Ponderosa pine	29	14	12	45
Douglas-fir	24	4	35	37
Engelmann spruce	—	—	80	20
Grand fir	17	27	33	23
Grand Fir/Blue Huckleberry Habitat Type				
Number of microplots	4	11	64	21
Lodgepole pine	—	29	42	29
Ponderosa pine	—	—	80	20
Douglas-fir	—	39	36	25
Engelmann spruce	—	—	67	33
Grand fir	—	38	24	38

Silvicultural Methods

Silvicultural activities influence the safe site both by altering the availability of site protection and by influencing the dispersal of seed to the safe site. In the Douglas-fir/white spirea h.t., the largest proportion of lodgepole pine and ponderosa pine seedlings was found under shelterwood cuts (table 6). As would be expected, seedlings occurred predominately in cutting units with a seed source for the particular species present within or close to the cutting unit. In the grand fir/mountain maple h.t., only Engelmann spruce and grand fir were most common in shelterwoods. Western larch and Douglas-fir occurred

predominately in seed-tree cutting units. In the grand fir/blue huckleberry h.t., lodgepole pine and Engelmann spruce were most common in shelterwood cuts, while ponderosa pine, Douglas-fir, and grand fir were predominate in clearcuts.

Species

Lodgepole Pine—Lodgepole pine regenerated best under shelterwood cuts in the Douglas-fir/white spirea and grand fir/blue huckleberry h.t. and best under seed-tree cuts in the grand fir/mountain maple h.t. Lodgepole pine is mostly nonserotinous in central Idaho (Steele and others 1981), and the high incidence of lodgepole pine seedlings under the shelterwood was probably because of an adequate seed source rather than the environmental conditions provided by the residual overstory. In south-central Oregon, Dahms (1963) found that 85 percent of the seed dispersed into clearcuts fell within 66 ft (20 m) of the seed source. Boe (1956) reported that in central Montana, 84 percent of the seed fell within 198 ft (60 m) of the seed source. Dahms (1963) recommends that clearcutting units should not be larger than 400 ft (122 m) across. Trappe (1959) suggests using long, narrow clearcuts or seed-tree cuts with seed-trees placed not more than 198 ft (60 m) apart.

For all three habitat types, most seedlings occurred on sites with light scarification. Trappe (1959), Boe (1956), Day and Duffy (1963), and Roe (1952) also found that lodgepole pine occurred most often on scarified sites on mineral soil. In central Idaho, mineral soil or moss mats were efficient, moderately efficient, or very efficient seedbeds. Most seedlings occurred in moderate shade in all three habitat types. Several covers were moderately efficient or very efficient for lodgepole pine including Utah honeysuckle (*Lonicera utahensis*), thimbleberry, blue huckleberry, and white spirea.

Western Larch—Western larch seedlings occurred exclusively in the grand fir/mountain maple h.t. Most seedlings were found under seed-tree cuts with a western larch overstory, particularly on sites with scarification. Boe (1953) found that western larch in northwestern Montana dispersed seed up to 396 ft (121 m). Shearer (1959), also working in northwestern Montana, reported that virtually all seed that disseminated farther than 264 ft (80 m) were released during good seed years and that the smaller the seed crop, the shorter the average dispersal distance. Shearer also indicated that most of the seed was disseminated by thermal slope winds generated by warm, dry weather rather than by prevailing winds. Boyd (1969) found in northern Idaho that clearcuts ranging from 264 to 462 ft wide (80 to 141 m) produced more seedlings than seed-tree cuts or shelterwood cuts. Mineral soils were the most common seedbeds in other areas (Boyd and Deitschman 1969; Roe 1952). However, in central Idaho, moss mats and rotten wood were very efficient seedbeds. Even though Roe (1952) found more western larch seedlings in light shade, most seedlings in central Idaho were found in moderate shade, particularly under blue huckleberry, currant (*Ribes* spp.), and Utah honeysuckle.

Table 6—Occurrence of tree seedlings (percentage) by silvicultural method and overstory composition for Douglas-fir/white spirea, grand fir/mountain maple, and grand fir/blue huckleberry habitat types

Silvicultural method	Percent cover	Percentage of sites	Species					
			Lodgepole pine	Western larch	Ponderosa pine	Douglas-fir	Engelmann spruce	Grand fir
Douglas-fir/White Spirea Habitat Type								
Clearcut		58	20	—	22	28	—	—
Seed-tree cut		18	0	—	21	26	—	—
----- Seedling occurrence (percent) within seed-tree cuts -----								
Ponderosa pine	7	67	—	—	100	¹ 45	—	—
Ponderosa pine	39	22	—	—	—	39	—	—
Douglas-fir	5							
Douglas-fir	15	11	—	—	—	16	—	—
Shelterwood cut		10	80	—	45	26	—	—
----- Seedling occurrence (percent) within shelterwood cuts -----								
Lodgepole pine	3	20	100		16	70	—	—
Ponderosa pine	15							
Douglas-fir	6							
Ponderosa pine	16	60	—	—	37	¹ 30	—	—
Ponderosa pine	20	20	—	—	47	—	—	—
Douglas-fir	15							
Selection cut		14	0	—	12	20	—	—
----- Seedling occurrence (percent) within selection cuts -----								
Lodgepole pine	15	14	—		—	11	—	—
Ponderosa pine	3							
Douglas-fir	18							
Ponderosa pine	24	43	—	—	—	29	—	—
Douglas-fir	8							
Ponderosa pine	11	29	—	—	14	5	—	—
Douglas-fir	15	14	—	—	¹ 86	55	—	—
Grand Fir/Mountain Maple Habitat Type								
Clearcut		66	5	9	12	22	30	20
Seed-tree cut		8	73	84	29	28	70	26
----- Seedling occurrence (percent) within seed-tree cuts -----								
Western larch	3	17	—	52	—	—	—	—
Western larch	3	17	100	39	—	—	100	70
Engelmann spruce	6							
Ponderosa pine	3	49	—	¹ 9	100	¹ 100	—	23
Grand fir	15	17	—	—	—	—	—	7
Shelterwood cut		11	0	7	0	32	0	44
----- Seedling occurrence (percent) within shelterwood cuts -----								
Western larch	3	13	—	100	—	56	—	18
Douglas-fir	33							
Grand fir	15							
Douglas-fir	18	13	—	—	—	—	—	13
Douglas-fir	13	61	—	—	—	10	—	5
Grand fir	12							
Grand fir	53	13	—	—	—	¹ 35	—	64
Selection cut		14	22	0	59	18	0	10
----- Seedling occurrence (percent) within selection cuts -----								
No cover	0	10	—	—	—	—	—	—
Lodgepole pine	3	10	—	—	—	—	—	55
Grand fir	3							
Ponderosa pine	3	10	100	—	—	—	—	—
Douglas-fir	15							
Grand fir	15							
Ponderosa pine	3	20	—	—	27	—	—	—
Grand fir	11							
Douglas-fir	18	10	—	—	—	30	—	16
Douglas-fir	15	10	—	—	—	15	—	24
Grand fir	3							
Grand fir	11	30	—	—	¹ 73	¹ 55	—	5

(con.)

(con.)

Table 6 (Con.)

Silvicultural method	Percent cover	Percentage of sites	Species					
			Lodgepole pine	Western larch	Ponderosa pine	Douglas-fir	Engelmann spruce	Grand fir
Grand Fir/Blue Huckleberry Habitat Type								
Clearcut		82	26	—	100	56	24	53
Seed-tree cut		7	0	—	44	44	0	24
----- Seedling occurrence (percent) within seed-tree cuts -----								
Ponderosa pine	15	50	—	—	—	—	—	100
Douglas-fir	3							
Engelmann spruce	3							
Douglas-fir	3	50	—	—	—	100	—	—
Grand fir	3							
Shelterwood cut		7	74	—	0	0	76	7
----- Seedling occurrence (percent) within shelterwood cuts -----								
Lodgepole pine	1	50	—	—	—	—	—	—
Grand fir	53							
Douglas-fir	15	50	100	—	—	—	100	100
Engelmann spruce	3							
Grand fir	18							
Selection cut		4	0	—	0	0	0	16
----- Seedling occurrence (percent) within selection cuts -----								
Engelmann spruce	18	100	—	—	—	—	—	100
Grand fir	45							

¹Seed source within 100 feet (30 m) of sample plot.

Ponderosa Pine—Ponderosa pine occurred most often in the warm, dry Douglas-fir/white spirea h.t. Here, ponderosa pine regeneration was highest under shelterwoods, while in both of the cooler, moister grand fir habitat types, regeneration was highest under selection cuts and on clearcuts. Ponderosa pine seed does not disseminate naturally over long distances; in central Oregon, most seed fell within 132 ft (40 m) of the seed source (Barrett 1966). Curtis and Foiles (1961) reported that in central Idaho, most ponderosa pine seed fell within 66 ft (20 m) of the seed source.

As with the lodgepole pine and western larch, scarification treatments produced the largest number of ponderosa pine seedlings. Tackle and Roy (1953), Roy (1983), and Shearer and Schmidt (1970) indicated that scarification treatments resulted in more seedlings than did other treatments. Foiles and Curtis (1965) reported that the seed-to-seedling ratio was 55:1 on scarified areas, while the ratio was 6,150:1 on unscarified areas. In the Douglas-fir/white spirea and grand fir/blue huckleberry h.t., light scarification was best, while in the grand fir/mountain maple h.t., most seedlings occurred from heavy scarification. Moss mats, rotten wood, and bare soil were moderately efficient and very efficient seedbeds in the Douglas-fir/white spirea and the grand fir/blue huckleberry h.t. Most seedlings were found in moderate shade in all three habitat types. Big sagebrush (*Artemisia tridentata*), thimbleberry, rose (*Rosa* spp.), and serviceberry (*Amelanchier alnifolia*) were very efficient covers.

Not all of the incidences of ponderosa pine resulted from natural seedfall. In the Douglas-fir/white spirea h.t., 16 percent of the occurrences of ponderosa pine resulted from seed caches. In both the grand fir/mountain maple

and grand fir/blue huckleberry h.t., 17 percent of the occurrences were in seed caches. In central Idaho, McConkie and Mowat (1936) found that 14 percent of the ponderosa pine occurrences were the result of seed caches. Saigo (1969) and West (1968), both working on the east side of the central Oregon Cascades, found that seedling caches occurred 21 and 15 percent, respectively.

Various animals have been implicated as the source of these seed caches. Giuntoli and Mewaldt (1978), in the Bitterroot Range in Montana, found that Clark's nutcracker (*Nucifraga columbiana*) ate and probably cached ponderosa pine seed in the same manner that limber pine (*Pinus flexilis*) and whitebark pine (*P. albicaulis*) are stored (Giuntoli and Mewaldt 1978; Lanner and Vander Wall 1980; Vander Wall and Balda 1977; Vander Wall and Hutchins 1983). Saigo (1969) indicated that most seed caches in her study area probably resulted from the golden-mantled ground squirrel (*Spermophilus lateralis*) or the yellow pine chipmunk (*Eutamias amoenus*). Both of these rodents are present in central Idaho. However, the yellow pine chipmunk was probably most common within the studied habitat types (Steele 1986). Other animals in the study areas, namely the Steller's jay (*Cyanocitta stelleri*) and deer mouse (*Peromyscus maniculatus*), also cache seed. However, these animals cache single seeds rather than groups of seed (Hofmann 1923; Lanner 1980). Seedlings that may have resulted from single seed caches could not be distinguished from seedlings that resulted from natural seedfall.

Douglas-fir—Douglas-fir occurrence was similar to the occurrence of ponderosa pine. It was highest in the Douglas-fir/white spirea h.t. and lowest in the grand fir/blue huckleberry h.t. Douglas-fir seedlings were found in

almost equal amounts under different silvicultural treatments in the Douglas-fir/white spirea h.t., though occurrence in clearcuts was slightly higher than occurrences under other treatments. However, in the grand fir/blue huckleberry h.t., more than half of the Douglas-fir seedlings were found in clearcuts. In grand fir/mountain maple, more seedlings were found under shelterwoods. In northwestern Montana, Douglas-fir seed dispersed up to 264 ft (80 m) (Boe 1953). Boyd (1969) found that most seedlings occurred in clearcuts in northern Idaho though slightly fewer were found in shelterwood cuts, while Day and Duffy (1963), working in Canada, recommend shelterwood cutting.

Scarification treatments favored Douglas-fir seedlings in both grand fir habitat types. However, broadcast burning was most beneficial in the Douglas-fir/white spirea h.t. Moderately efficient seedbeds were moss mats in Douglas-fir/white spirea and grand fir/mountain maple h.t., residual duff in grand fir/mountain maple h.t., and rotten wood in grand fir/blue huckleberry h.t. Roe (1952) found most seedlings on mineral soil, but Day and Duffy (1963) reported that moss mats and decayed wood were better seedbeds than mineral soil. In the Douglas-fir/white spirea h.t., white spirea, ceanothus (*Ceanothus velutinus*), slash, and bitterbrush (*Purshia tridentata*) were moderately efficient cover. Blue huckleberry, mountain maple, and pachistima (*Pachistima myrsinites*) were moderately efficient in grand fir/mountain maple h.t., and thimbleberry and pachistima were very efficient in grand fir/blue huckleberry h.t. Most seedlings were found under heavy canopy cover. On other areas, seedlings were found more commonly under light or moderate cover (Roe 1952) or no cover (Day and Duffy 1963).

Engelmann Spruce and Grand Fir—Both Engelmann spruce and grand fir occurred only in the grand fir habitat types. Engelmann spruce seedlings were predominate under seed-tree cuts in grand fir/mountain maple h.t. and under shelterwoods in grand fir/blue huckleberry h.t. Squillace (1954), working in Montana, suggested that openings of 1,188 ft (362 m) to 1,320 ft (402 m) are maximum size for obtaining good Engelmann spruce regeneration. However, Alexander (1969) in Colorado reported that most seed fell within 198 ft (60 m) of the seed source even though seed was dispersed as far as 396 ft (121 m) during years of moderate seed production. Ronco (1973) found that most seed fell within 99 ft (30 m). Alexander and others (1986) recommended that clearcut openings should be no larger than 450 ft (137 m). Roe (1952) states that clearcutting should only be used on north or east aspects when Engelmann spruce seedlings are desired; shelterwood cuts should be used on south or west aspects. Boyd (1969) found that more seedlings occurred in clearcuts in northern Idaho than in seed-tree cuts or shelterwood cuts.

All seedlings were found on sites with scarification, predominately light scarification. Roe (1952), Boyd and Deitschman (1969), Smith (1954), and Fiedler and others (1985) all reported that most Engelmann spruce seedlings occurred on scarified sites with exposed mineral soil. Day (1964) and Day and Duffy (1963) found that moss and decayed wood were better seedbeds than was mineral soil. In central Idaho, moss mats were very efficient seedbeds

in all three habitat types. Most seedlings occurred under heavy shade in grand fir/mountain maple h.t., and under light shade in grand fir/blue huckleberry h.t. Thimbleberry, Sitka alder, and mountain ash (*Sorbus scopulina*) were very efficient covers in grand fir/mountain maple h.t. Thimbleberry, Engelmann spruce, and Scouler willow (*Salix scouleriana*) were very efficient or moderately efficient in grand fir/blue huckleberry h.t.

Most grand fir seedlings were found under shelterwoods in grand fir/mountain maple h.t. and in clearcuts in grand fir/blue huckleberry h.t. Boyd (1969) in northern Idaho found more grand fir seedlings in seed-tree cutting units than in clearcuts or shelterwood cuts. Seedling occurrence was highest on scarified sites in both habitat types. Residual duff was a very efficient seedbed in grand fir/mountain maple h.t., and rotten wood was very efficient in grand fir/blue huckleberry h.t. More seedlings occurred in moderate or heavy shade. Mountain maple and russet-buffaloberry (*Shepherdia canadensis*) were very efficient covers in grand fir/mountain maple h.t., and thimbleberry was very efficient in grand fir/blue huckleberry h.t.

RECOMMENDATIONS

Following are recommendations for the observed species in the Douglas-fir/white spirea, grand fir/mountain maple, and grand fir/blue huckleberry habitat types in central Idaho.

Douglas-Fir/White Spirea Habitat Type

Lodgepole Pine—Because lodgepole pine is mostly non-serotinous in central Idaho (Steele and others 1981) care must be taken to maintain the species' residual overstory. Small clearcuts, seed-tree cuts, and shelterwood cuts can be used. All sites should be lightly scarified. Complete removal of competing vegetation is not necessary because lodgepole pine can establish in moderate shade.

Ponderosa Pine—Ponderosa pine is a heavy-seeded species (Minore 1979), so seed-tree cuts and shelterwoods are effective. Light scarification is desired, but seedlings will establish on heavily scarified sites under bitterbrush and big sagebrush. Seedlings will also establish in moderate shade under ceanothus, which often occurs after broadcast burning.

Douglas-fir—Any silvicultural treatment can be used to establish Douglas-fir seedlings. However, clearcuts should be kept small to ensure adequate seed dispersal from the surrounding stand. Broadcast burning or scarification can both be effective. On scarified sites, scattered slash can be used to protect seedlings.

Grand Fir/Mountain Maple Habitat Type

Lodgepole Pine—The recommendations for lodgepole pine in grand fir/mountain maple h.t. are the same as those for lodgepole pine in the Douglas-fir/white spirea h.t.

Western Larch—Lightly scarified seed-tree cuts are useful to regenerate western larch. Seedlings will establish well under moderate shade of blue huckleberry, currant, and Utah honeysuckle.

Ponderosa Pine—Small clearcuts or ponderosa pine seed-tree cuts with heavy scarification are effective. Seedlings will establish under moderate shade, particularly under thimbleberry and rose.

Douglas-fir—Small clearcuts, seed-tree cuts, or shelterwoods can be used. Douglas-fir seedlings will establish on residual duff, but regeneration is best on sites with light or heavy scarification. Seedlings will establish under most covers, although regeneration may be low on sites with high coverage of ninebark.

Engelmann Spruce—Shelterwoods or brushy seed-tree cuts that have been lightly scarified should regenerate well. Seedlings will establish under heavy shade, particularly on sites with Sitka alder, thimbleberry, and mountain-ash.

Grand Fir—Scarified shelterwoods are best. Broadcast-burned clearcuts that provide moderate shade should also regenerate well.

Grand Fir/Blue Huckleberry Habitat Type

Lodgepole Pine—Small clearcuts, seed-tree cuts, or shelterwood cuts with good lodgepole pine seed sources around or within the cutting unit are effective. Light scarification is best. Seedlings will establish in moderate shade, particularly on sites with Utah honeysuckle, white spirea, and thimbleberry.

Ponderosa Pine—Good seedling establishment should occur on small, lightly scarified clearcuts or seed-tree cuts with well-placed seed-trees. Seedlings should establish well in moderate shade, especially on sites with thimbleberry.

Douglas-fir—Small clearcuts and seed-tree cuts should produce good results. Both scarification and broadcast burning can be used. Seedlings will regenerate under heavy shade, particularly on sites with thimbleberry and pachistima.

Engelmann Spruce—Lightly scarified shelterwoods can be used to regenerate Engelmann spruce. Seedlings will do well under light cover, particularly under the cover of thimbleberry, blue huckleberry, Scouler willow, and Utah honeysuckle.

Grand Fir—Small scarified or broadcast-burned clearcuts that produce heavy shade cover will regenerate well. Cover of thimbleberry, blue huckleberry, and Scouler willow should provide good cover.

Even though stocking of natural seedlings currently is low in central Idaho, natural regeneration can be used as a viable alternative to planting. While the results of this study are not conclusive, data from this and other investigations should help to determine the best methods to regenerate natural seedlings. With further study and careful application of silvicultural treatments and site preparations, stocking of natural regeneration should increase in time.

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Microsite seedbeds and covers were surveyed for six conifer species following various silvicultural-site preparation combinations in three central Idaho habitat types. Seedling occurrence was related to seedbeds, cover, site preparation method, and silvicultural method. An index was developed to indicate potential beneficial or detrimental seedbeds or covers for each species. Recommendations are listed for silvicultural-site preparation practices to obtain desired natural regeneration in the three habitat types.

KEYWORDS: natural regeneration, microsites, central Idaho

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