Emergence and Survival of Redstem *(Ceanothus sanguineus)* Following Prescribed Burning[1]

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INTRODUCTION

LARGE wildfires during the 1910-1934 period caused brushfields to replace conifer forests over much of the St. Joe and Clearwater River drainages in northern Idaho. Large elk herds use the low elevation brushfields for winter range and redstem (*Ceanothus sanguineus*) makes up about one-third of their winter diet (Trout and Leege, 1971).

Redstem ceanothus is an erect, loosely branched shrub that is normally 3 to 9 feet tall at maturity. Its habitat ranges from southern British Columbia to northern California and eastward to Montana and Wyoming. It is also found in the central great lakes region (Hickey and Leege, 1970). In Idaho, redstem is widely distributed, but especially abundant north of the main Salmon River. This plant reaches its peak densities in shrub seres that follow wildfires and logging on

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Pinus ponderosa/and *Pseudotsuga menziesii*/*Physocarpus* habitat types and *Abies grandis*/and *Thuja plicata*/*Pachistima*, habitat types, *Physocarpus* undergrowth union.

Redstem owes its existence naturally to wildfires (Hickey and Leege, 1970). Its seeds have a hard, impermeable coat and a dormant embryo which is not fully developed (Glazebrook, 1941). Seed germination will not occur until two separate requirements are met: plumping and stratification (Quick and Quick, 1961). The seed hilum acts as a valve; it allows the seed to dry out but does not allow it to absorb moisture. Heat causes the hilar fissure to permanently open and allow water to enter the seed (plumping). However, seeds will still not germinate until embryo dormancy is broken by appropriate stratification treatment; i.e., moist aerated storage through the winter at temperatures slightly above freezing.

In the past, redstem made up a larger part of the shrubfield composition than it does now (Trout and Leege, 1971). Conifers and tall-growing shrubs are replacing redstem which is very intolerant of shade and relatively short lived. Because of the loss of browse on winter ranges, the Idaho Fish and Game Department, in 1965, initiated a study of the use of prescribed burning to rejuvenate the overmature brushfields. One objective of the burning was to cause redstem seed germination and seedling establishment. Results from that phase of the study are presented in this paper.

STUDY AREAS

Study sites along the Lochsa River, north-central Idaho, were chosen for evaluating prescribed burning (Fig. 1) (Table 1). The Lochsa flows in a west-southwesterly direction from its headwaters in the Bitterroot Range, and joins the Selway River at Lowell, Idaho, to form the Middle Fork of the Clearwater River. The drainage is characterized by narrow canyons and steep slopes. Elevations range from 1460 feet at Lowell, Idaho to 8800 feet in the peaks of the Bitterroot Mountains.

Weather follows a pattern of cool, rainy springs; hot, dry summers; cool, rainy falls; and rainy and snowy winters. Weather records at Fenn Ranger Station near the mouth of the Lochsa River show that

January has the highest average precipitation (5.88 in.) and July the lowest (0.45 in.). Average annual precipitation for the 8 years of the study was 38.63 inches.

The vegetation of the Lochsa drainage has been greatly influenced by fire. Much of the lower elevation area below 3500 feet was burned by wildfires in the 1929-1934 period (Norberg and Trout, 1957). The south and west aspects at these low elevations are still predominantly a seral shrub community. Succession is advancing faster on the north and east aspects with more conifers in the plant community.

Our study sites were located within the *Thuja plicata/Pachistima* and *Abies grandis/Pachistima* habitat types as described by Daubenmire and Daubenmire (1968). These two habitat types are the dominant ones at elevations below 4000 feet where elk are normally found during the winter and spring months. *Thuja/Pachistima* is the major habitat type, but is replaced by the *Abies/Pachistima* type on the drier southerly exposures.

The seral brushfields associated with these habitat types generally include a variety of shrub species. Tall shrubs commonly occurring are: *Acer glabrum, Amelanchier alnifolia, Prunus emarginata, Salix scouleriana,* and *Cornus nuttallii.* Medium shrubs include: *Ceanothus sanguineus, C. velutinus, Physocarpus malvaceus, Rhamnus purshiana, Holodiscus discolor, Philadelphus lewisii,* and *Cornus stolonifera.* Predominant low growing shrubs are: *Rubus parviflorus, Lonicera utahensis, Symphoricarpos albus, Spiraea betulifolia, Pachistima myrsinites,* and *Vaccinium membranaceum.*

Comprehensive reviews of the geology of the area have been made by Roper (1970) and Steele (1971). Bedrock consists of igneous intrusive rocks of the Idaho batholith.

Soils are moderately deep and well-drained. They grade from a fine sandy loam on the surface to a loamy sand at lower depths. These soils have developed from a parent material of residium from hornblende-biotite quartz dioritic orthogneiss, and belong to the Jughandle or closely related soil series (Hickey, 1971; Roper, 1970).

METHODS

We studied redstem seedling emergence and survival after pre-

Table 1. Characteristics of the Study Sites in the Lochsa River Drainage

Study Site	Aspect	Elevation	Avg. Slope	Habitat Type	Vegetation Type	Last Wildfire	Burning Treatment
Holly Cr.	Southwest	2700	60%	Red Cedar/ Pachistima	willow, redstem serviceberry	1929	Spring, 1966
Otterslide Cr.	South Southwest	2100	75%	Grand Fir/ Pachistima	willow, redstem bitter cherry	1934	Spring, 1966
Sherman Cr.	South Southwest	2200	69%	Grand Fir/ Pachistima	willow, redstem bitter cherry	1934	Spring, 1966
Polar Ridge	South	3000	75%	Grand Fir/ Pachistima	willow, redstem bitter cherry	1934	Spring, 1969
Polar Ridge	West	3200	65%	Red Cedar/ Pachistima	Doug. fir, willow bitter cherry	1934	Spring, 1969
Otterslide Control	South	2100	61%	Grand Fir/ Pachistima	willow, redstem bitter cherry	1934	Spring, 1970
Placer Cr.	South	3000	65%	Grand Fir/ Pachistima	willow, redstem bitter cherry	1934	Spring, 1971
Otterslide	South Southwest	2100	75%	Grand Fir/ Pachistima	willow, redstem bitter cherry	1934	Fall, 1965
Sherman Cr.	Southwest	2200	81%	Grand Fir/ Pachistima	willow, redstem bitter cherry	1934	Fall, 1966
Placer Cr.	East	2100	77%	Red Cedar/ Pachistima	grand fir, willow bitter cherry	1934	Fall, 1971
Placer Cr.	West	2100	54%	Grand Fir/ Pachistima	Doug. fir, willow bitter cherry	1934	Fall, 1971
Polar Ridge	East	3100	60%	Red Cedar/ Pachistima	grand fir, willow bitter cherry	1934	Fall, 1972

scribed burning on 12 sites (Table 1). Seven sites were burned in the spring, whereas five were treated in the fall. All of the areas were ignited from the ground using propane or diesel back pack torches or back-fire fusees. On Polar Ridge East, some of the vegetation was slashed before burning.

On all of the study sites, except those on Placer Creek, redstem seedling emergence and survival was only one of many burning effects being evaluated. Permanent circular or square plots were established along a transect line in order to measure changes in redstem numbers. These plots varied in size and number depending upon the objectives of the study and past experience. A plot size of 43.6 square feet was first used, but this proved to be too large and smaller plots of 10 or 2.1 square feet were used in later years. Redstem seedlings were usually counted within these plots during the spring when they first appeared, and periodically thereafter, to document establishment.

The Placer Creek study was initiated for the specific purpose of studying survival and growth of redstem seedlings after spring and fall burning. On the spring burn, plots were placed where seedlings were abundant so we could document survival of a larger sample. On the fall burns, plots were systematically established along a transect line at 20 foot intervals. All plots were read bi-weekly during the first summer after seedling emergence. General observations were also made on seedlings outside of the plots. Soil moisture on a percent dry weight basis was recorded for the top 8 inches of the soil profile.

Temperature and precipitation data from the weather station maintained by the United States Forest Service at Fenn Ranger Station (Fig. 1) were used to give an approximation of climatic conditions on our study sites.

RESULTS

Seedling Emergence

Spring and fall prescribed burns were successful in providing the heat necessary for redstem seeds to germinate. Data from the Holly Creek study area show the typical sequence of events which followed a spring burn (Table 2). Holly Creek was burned in May, 1966. We

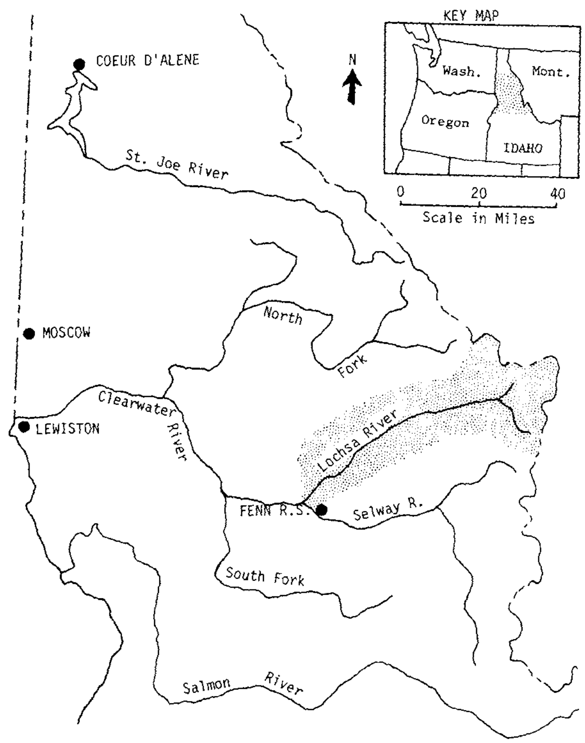

Figure 1. Area map of north-central Idaho.

checked our study plots in August, 1966, and found 14 redstem seedlings despite the fact that seeds usually require a period of cold stratification following burning before germination will occur. Apparently some seeds did not need the stratification as they germinated soon after burning. Most of the seedlings (96%) emerged 1 year following the burning treatment, in May 1967. A decreasing number of seedlings emerged in each of the following 3 years and occasionally thereafter.

The pattern for seedling emergence following fall burning was the same as for spring burning except seedlings did not emerge immediately after the fall burns like we found after some spring burns (Table 3).

Table 2. Redstem seedling emergence on spring burns.

Study Area	No. of Plots	Plot Size[1]	When Burned	Newly Emerged Seedling Counts and Per Acre Estimates on Various Dates[2]				
Holly Cr.[3]	40	43.6	May 2, 1966	Aug. 19, 1966* 14 350/acre	May 23, 1967 2074 51,922/acre	May 27, 1968 41 1,026/acre	May 16, 1969 18 451/acre	May 14, 1970 8 200/acre
Otterslide Cr.	8	2.1	March 30, 1966	July 27, 1966* 0	May 4, 1967 13 33,707/acre	May 29, 1968 2 5,186/acre		
Sherman Cr.	8	2.1	April 6, 1966	Aug. 3, 1966* 2 5,186/acre	May 18, 1967 31 80,379/acre	May 28, 1968 2 5,186/acre		
Polar Ridge South	50	10	April 16, 1969	May 22, 1970 137 11,935/acre				
Polar Ridge West	28	10	May 6, 1969	May 22, 1970 211 32, 826/acre	Sept. 15, 1971* 5 778/acre			
Otterslide Control	19	2.1	May 4, 1970	June 17, 1971 66 72,054/acre				
Placer Cr.[4]	10	10	May 11, 1971	June 13, 1972 349	May 29, 1973 10			

[1]Plot sizes are in square feet.

[2]Dates are when the seedlings were counted for the first time.

[3]Some of the seedlings on Holly Cr. may have been *Ceanothus velutinus.*

[4]Seedling plots at Placer Cr. were placed in selected areas with high seedling concentrations; therefore per acre estimates would be invalid.

*Counts made in July, August, and September are minimums; many more were probably present earlier in the summer and died.

Table 3. Redstem seedling emergence on fall burns.

Study Area	No. of Plots	Plot Size[1]	When Burned	Newly Emerged Seedling Counts and Per Acre Estimates on Various Dates[2]		
Otterslide Cr.	5	2.1	Oct. 12, 1965	July 29, 1966* 50 207,429/acre	May 4, 1967 4 16,594/acre	May, 1968 2 8,297/acre
Sherman Cr.	15	2.1	Oct. 10, 1966	May 18, 1967 175 242,000/acre	May 29, 1968 16 22,126/acre	
Placer Cr. East	10	10	Sept. 22, 1971	June 2, 1972 505 219,978/acre	May 29, 1973 1 436/acre	
Placer Cr. West	10	10	Sept. 22, 1971	June 2, 1972 352 153,331/acre	May 29, 1973 1 436/acre	
Polar Ridge East	20	10	Oct. 6, 1972	May 26, 1973 487 106,069/acre		

[1]Plot sizes are in square feet.

[2]Dates are when the seedlings were counted for the first time.

*Since some mortality would have occurred by July 29, this estimate of seedlings is definitely a minimum.

New seedlings began appearing on burned areas during the month of April. Most seedlings emerged by the end of May, with a few additional arrivals during June and July.

The number of seedlings that emerged following fall burning was always greater than after spring burning. When seedling counts on plots were converted to seedlings per acre, fall burns had 186,000, compared with 47,000 seedlings on spring burns (Fig. 2). The Sherman Creek fall burn had the highest number of seedlings per acre—242,000 (Table 3). The highest number of seedlings produced from a spring burn was also at Sherman Creek with 80,000 per acre (Table 2). Seedlings per acre were not computed for the Placer Creek spring burn because plots were biased by being placed in areas of high seedling densities.

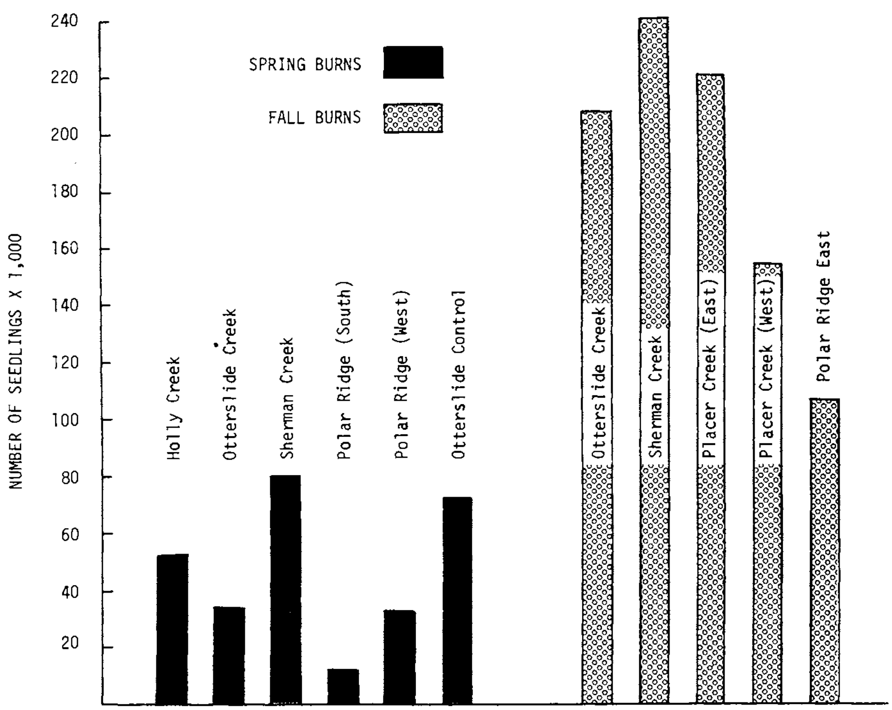

Figure 2. Number of seedlings emerging per acre on spring and fall prescribed burns.

Seedling emergence increased with burn intensity. Where fires were hottest, as around logs, stumps, and slash accumulations, redstem seedlings were generally more numerous. Fall burns were hotter and more consumptive than spring burns, and consequently, seedling emergence was greater and more uniformly distributed over the fall-burned sites.

Growth of Redstem Seedlings

We found a great variation in seedling growth following spring and fall burning. The best growth usually occurred on the fall burns. First year seedlings on spring burned areas were consistently small whereas those on the fall burns had a greater size range and a larger average size (Fig. 3).

We evaluated more closely the differences in seedling growth be-

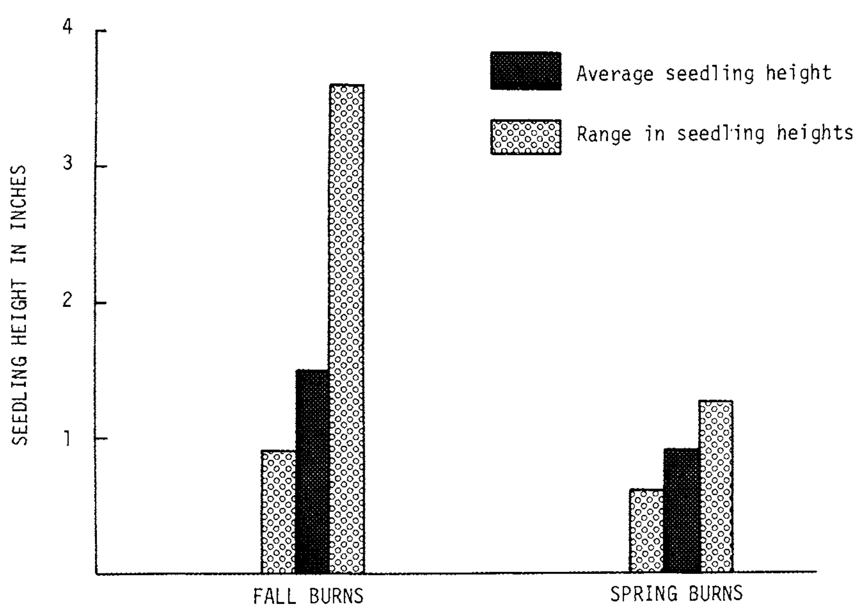

Figure 3. Heights of 4-month old seedlings in our study plots on fall and spring prescribed burns.

tween spring and fall burns on the Placer Creek study area. At the end of the first summer of growth, the seedlings on the fall burn at Placer Creek were significantly taller than the seedlings on the spring burn ($P=.10$). Seedlings on the spring burn reached 90 percent of their height by the end of June, while seedlings on the fall burns, with 71 percent of their height reached by the end of June, continued to grow throughout the summer. We also observed that the most rapid growing and healthiest looking seedlings occurred in the more intensely burned areas. These seedlings were usually growing in full sunlight with a noticeable lack of competing vegetation.

In order to eliminate the effect of aspect when evaluating seedling growth on fall and spring burns, we compared data from the spring burn on the Polar Ridge West site and the fall burn on the Placer Creek West study area. Despite the fact that the Polar Ridge site was higher in elevation, and therefore more moist, seedling growth was greater on the Placer Creek area, where burning was done in the fall (Table 4).

Soil moisture was measured periodically throughout the first summer on the Placer Creek Study Areas (Table 5). No statistically significant differences were found between the spring and fall burn areas; however, the spring burn was usually higher in soil moisture throughout the summer. Soil moisture alone is apparently not responsible for the growth differences observed on the study sites.

An analysis of the soil from the Placer Creek study areas indicated that nitrate nitrogen, ammonium, phosphorus, zinc, manganese, iron, boron, calcium, and the salt content (Ec) of the soil were all higher on the burn sites than the control (Table 6). Comparing just the burn areas, nitrate nitrogen, zinc, and manganese were higher on the fall burn sites. Best seedling growth occurred on the severe burn areas and those had the highest nitrate nitrogen levels.

We collected soil from the Placer Creek study areas to use in growth experiments in controlled environment chambers. No fertilizers or nutrients were added to the soil as we wanted to compare our results with seedlings grown in the field on sites where we collected the soil. We obtained opposite results in the growth chamber tests as seedlings grown on the spring-burn soil were significantly taller than seedlings grown on the fall-burn soil ($P=.01$) (Fig. 4). Seedlings grown on both

Table 4. Height of redstem seedlings on some of the study areas.[1]

Study Area	Burning Treatment	Average and Ranges in Heights of Seedlings in Inches	
		4 Months	16 Months
	SPRING		
Holly Creek	May 2, 1966	1.0 (.5-2.5)	3.0 (.5-20)
Polar Ridge South	April 16, 1969	.7 (.5-1.0)	2.1 (1.0-3.0)
Polar Ridge West	May 6, 1969	1.0	1.6 (1.0-4.5)
Placer Creek South	May 11, 1971	1.1 (.6-1.5)	2.33 (2.0-3.0)
	FALL		
Placer Creek East	Sept. 22, 1971	1.7 (1.0-3.1)	5.1 (3.5-6.5)
Placer Creek West	Sept. 22, 1971	1.7 (.6-4.7)	2.6 (1.5-3.7)
Polar Ridge East	Oct. 6, 1972	1.0 (.5-3.0)	

[1]Seedling heights were not measured on all of the study areas.

Table 5. Soil moisture[1] on two fall burn sites and one spring burn site at Placer Creek during the summer of 1972.

Site	June 27	July 12	July 27	Aug. 12	Aug. 30	Sept. 26
Spring Burn South Aspect	35%	11.0%	23.0%	13.5%	11.5%	22.8%
Fall Burn West Aspect	29%	15.9%	14.0%	10.0%	11.5%	23.5%
Fall Burn East Aspect	29%	10.0%	8.7%	5.4%	3.6%	20.0%

[1]Soil moisture is on a percent dry weight basis. Field capacity is approximately 35%. Wilting point is approximately 10%.

spring and fall burn soils were taller than seedlings grown on the control soil. Apparently soil nutrients in the spring-burn soils were adequate for good seedling growth, and other factors in the field were responsible for depressed seedling growth. These factors could be competition with other plants for sunlight, moisture, and nutrients.

Table 6. Nutrient analysis of soils from the Placer Creek prescribed burns and a control.[1]

Burning Treatment	ppm NO_3	ppm NH_3	pH	ppm P	ppm K[2]	% OM	ppm Zn	ppm Mn	ppm Fe	ppm Cu	ppm B	ppm Ca	ppm Mg	ppm K[3]	Ec[4]
Placer Creek Severe Fall Burn	9.64	31.4	6.10	8.5	171.5	3.29	1.30	90.0	105.0	1.65	.25	700	112	113.4	0.80
Placer Creek Normal Fall Burn	3.38	31.6	6.30	6.7	195+	2.80	1.10	96.0	100.0	1.90	0.40	770	152	125.1	0.78
Placer Creek Severe Spring Burn	3.05	36.2	6.00	12.0	195+	3.63	1.00	80.0	145.0	1.90	0.52	730	216	121.2	0.73
Placer Creek Cool Spring Burn	1.52	15.2	6.23	11.2	195+	4.80	1.25	43.0	125.0	1.80	0.36	660	152	140.8	0.30
Placer Creek Control No Burn	0.46	9.8	6.20	2.2	195+	3.35	0.80	59.0	75.0	1.70	0.21	430	160	144.7	0.30

[1]Placer Creek fall burn occurred in the fall, 1971.
Placer Creek spring burn occurred in the spring, 1971.
Soil for the nutrient analysis was collected on July 4, 1972 when redstem seedlings were actively growing.

[2]This potassium is sodium acetate extractable; a measure of relative availability.

[3]Total extractable potassium.

[4]Salt content measured in mmhos/cc

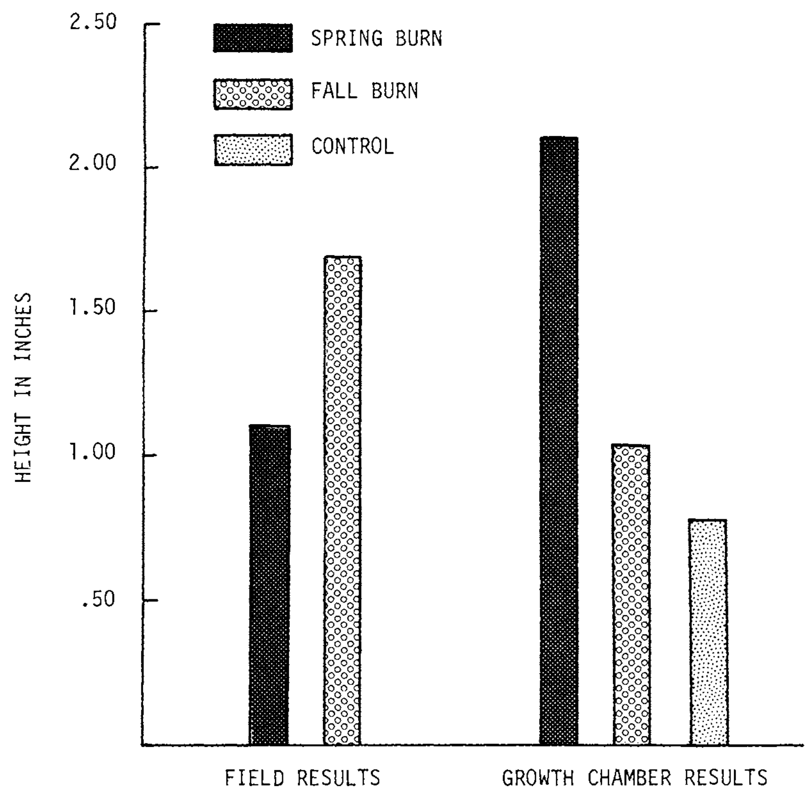

Figure 4. Height of 4-month old redstem seedlings from Placer Creek study areas compared with height of 40-day old seedlings grown in controlled growth chambers using soil from the Placer Creek study areas.

Seedling Survival

There are many interrelated factors affecting the survival of redstem seedlings. We were able to associate survival with summer precipitation, aspect, burning treatment, seedling growth, and elevation. In almost all cases our sample sizes were too small or too variable, or data were not collected at comparable time periods to make valid statistical tests. However, our data and judgments are strengthened by 8 years of field observations.

Most of the seedling losses occurred during the first 12 months after seedling emergence. Averaging all of our study sites, 30.2 percent of all seedlings survived their first summer. However, losses continued through the winter and only 3.4 percent of the seedlings were alive at the beginning of the second growing season.

Seedlings alive at the beginning of their second summer usually remained to become established in the plant community. Eighty-two percent of all seedlings alive at the beginning of their second summer survived their second summer.

Effect of Summer Precipitation:—Summers in the Lochsa River drainage are characteristically dry and warm, but vary considerably from year to year (Table 7). The summer of 1967 was the driest of the 8 study years. There was a 74-day period during that summer when less than 1/10 inch of precipitation was recorded at the Fenn Ranger Station, and the average maximum temperature for July, August, and September was 92.2°F, compared with the 8 year average of 85.5°F. The study areas of three spring burns (Holly Creek, Otterslide Creek, Sherman Creek) and two fall burns (Otterslide Creek, Sherman Creek) had new redstem seedlings emerging in the spring of 1967 (Tables 8 and 9). Less than 1 percent of the total seedlings on these areas survived until their second growing season.

The following summer of 1968 was the wettest summer during the study. Sixty-eight percent of the new seedlings emerging in the spring of 1968 on Holly Creek survived their first 12 months. The summer of 1970 was the second wettest summer, and 16 percent of the seedlings emerging on the two Polar Ridge spring burns in 1970 were still alive after two growing seasons (Table 8).

To say that total summer precipitation was solely responsible for these differences in seedling survival would be misleading. Soil moisture usually remained fairly high until the middle of July, and dropped to low levels in late summer. Precipitation received during late July and August was probably most important for seedling survival. In 1968, August precipitation was 3.18 inches, considerably above the amount normally received during that month.

Effect of Aspect:—We compared the effect of aspect on seedling survival on two study sites. One area was the Polar Ridge spring burns of 1969 where the majority of redstem seedlings emerged in

Table 7. Temperature (°F) and precipitation (in.) for Fenn Ranger Station during the summer months, 1966-1973.

	May		June		July		August		September		Total
Year	Max. Temp.	Precip.	Avg. Max. Temp.	Precip.	Avg. Max. Temp.	Precip.	Avg. Max. Temp.	Precip.	Avg. Max. Temp.	Precip.	Summer Precip.
1966	75.2	1.15	74.7	3.90	91.5	.02	91.4	1.55	82.3	.99	7.61
1967	74.1	2.76	79.1	2.86	93.8	.08	97.2	.01	85.6	1.80	7.51
1968	69.1	3.17	75.8	2.89	91.6	.42	83.7	3.18	72.5	4.48	14.14
1969	74.7	2.77	79.7	3.44	86.7	.24	90.5	.00	76.9	2.81	9.26
1970	70.1	2.31	81.7	3.18	87.8	1.00	91.6	.00	68.1	4.86	11.35
1971	72.4	3.53	72.8	4.14	87.7	.37	93.7	.31	71.0	1.95	10.30
1972	76.9	2.57	78.4	2.60	87.6	1.36	91.2	1.00	71.8	2.44	9.97
1973	74.1	2.02	75.3	3.22	90.5	.07	91.1	.18	74.6	3.02	8.51
8 yr. Avg. Precip.		2.54		3.28		.45		.78		2.79	
8 yr. Avg. Max. Temp.	73.3		77.2		89.7		91.3		75.4		

Table 8. Redstem seedling survival on spring burns.

Study Area	Date of First Count	No. of Seedlings	Percent of seedlings surviving up-to 16 months of age (two growing seasons)		
			4 Months	12 Months	16 Months
Holly Cr.	Aug. 19, 1966**	14 350/acre	–	71%	36%
	May 23, 1967	2074 51,922/acre	33%	3%	2%
	May 27, 1968*	41 1,026/acre	39%	54%	68%
Otterslide Cr.	May 4, 1967	13 33,707/acre	8%	0	0
	May 29, 1968	2 5,186/acre	0	0	0
Sherman Cr.	Aug. 3, 1966**	2 5, 186/acre	–	0	0
	May 18, 1967	31 80,379/acre	0	0	0
	May 28, 1968	2 5,186/acre	50%	0	0
Polar Ridge South	May 22, 1970	137 11,935/acre	15%	–	5%
Polar Ridge West	May 22, 1970	211 32,826/acre	48%	–	28%
Otterslide Control	June 17, 1971	66 72,054/acre	18%	–	–
Placer Cr.[1]	June 13, 1972	349	15%	1%	1%
	May 29, 1973	10	10%		

[1]Seedling plots at Placer Creek were placed in selected areas with high seedling concentrations; therefore, per acre estimates would be invalid.

*It is easy to miss small seedlings when counts are made, thus the survival of this age class increased as seedling size increased.

**These plots were not read until August. There were probably more seedlings present earlier in the summer.

–No data.

1970. Sixteen months after emergence, 5 percent of the seedlings on the south aspect survived, compared with 28 percent on the west aspect (Table 8). On the Placer Creek fall burns of 1971, we were able to compare east and west aspects, and found no difference between seedling survival on the two aspects (Table 9).

Seedling survival was very poor on south and southwest aspects ex-

Table 9. Redstem seedling survival on fall burns.

Study Area	Date of First Count	No. of Seedlings	Percent of seedlings surviving up-to 16 Months of Age (two growing seasons)		
			4 Months	12 Months	16 Months
Otterslide Cr.	July 29, 1966*	50 207,429/acre	—	10%	0
	May 4, 1967	4 16,594/acre	25%	0	0
	May, 1968	2 8,297/acre	0	0	0
Sherman Cr.	May 18, 1967	175 242,000/acre	9%	1%	1%
	May 29, 1968	16 22,126/acre	13%	—	—
Placer Cr. East	June 2, 1972	505 219,978/acre	28%	2%	2%
	May 29, 1973	1 436/acre	0		
Placer Cr. West	June 2, 1972	352 153,331/acre	31%	4%	3%
	May 19, 1973	1 436/acre	0		
Polar Ridge East	May 26, 1973	487 106,069/acre	40%		

*These plots were not read until July, there were probably more seedlings present earlier in the summer.
—No data.

cept during the two wet summers of 1968 and 1970 when seedling survival definitely improved.

Effect of Fall vs. Spring Burns:—There were indications that seedling survival was better following fall burning and we attempted to evaluate this possibility at the Placer Creek sites. Seedling mortality began almost immediately after emergence. Fifty-eight percent of all seedling mortality occurred by the end of July. Most of this early mortality was due to: 1) Predation by rodents or insects; and 2) A loss of chlorophyll in the cotyledons and leaves. This loss of chlorophyll may be associated with damping off of the roots. Thirty-five percent of all seedling mortality occurred during the month of August, with the main factor being desiccation due to the normally dry summer conditions.

In September, seedling mortality almost stopped on the fall burns, but on the spring burn, losses continued. At the end of September, 29 percent of the seedlings survived on the fall burns compared with 15 percent on the spring burns (Fig. 5).

Differences in survival between spring and fall burns did not show up until the end of the summer. The ability of seedlings to survive the summer drought was probably correlated with their size and vigor. The seedlings growing in areas without competition and around burned out stumps under the driest of conditions were usually large and showed no effects of desiccation. These conditions were most commonly associated with fall burns. However, the little seedlings which grew under heavy shade canopies on both spring and fall burns suc-

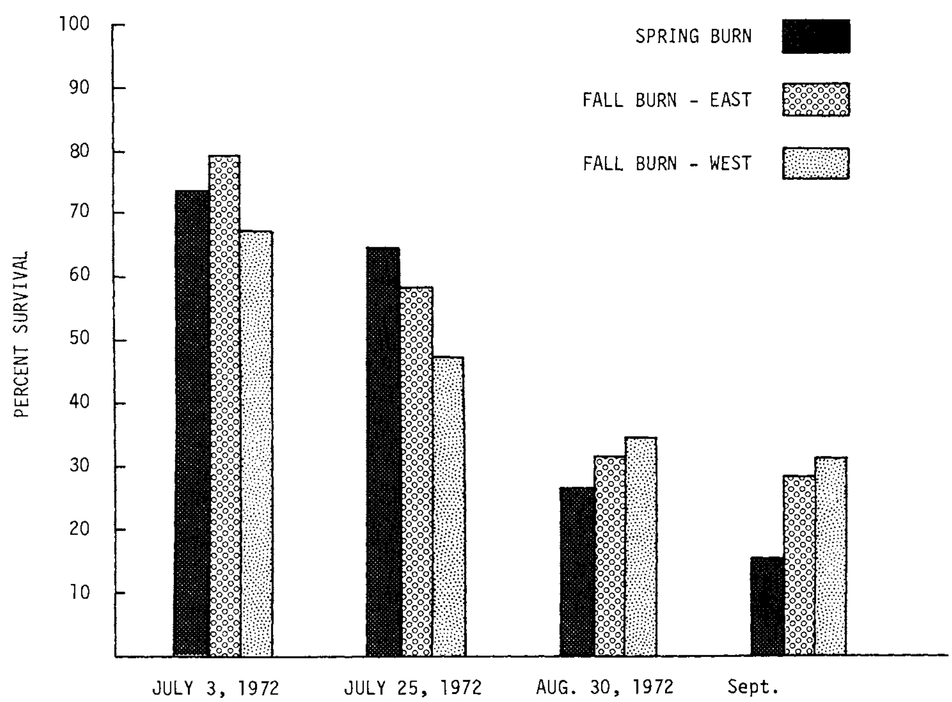

Figure 5. First summer seedling survival on Placer Creek spring and fall prescribed burns.

cumed to the dry conditions (Fig. 6, 7 and 8). Soil moisture in the spring and fall burns at Placer Creek was not significantly different (Table 5).

Effect of Elevation:—Five study areas were about 3,000 feet in elevation and seven study areas were near 2,000 feet. Prescribed burning in the areas near 3,000 feet was successful in causing new redstem seedlings to establish in the plant community. At 2,000 feet elevation, seedling survival was very poor, especially on spring burns, where seedling mortality was almost 100 percent. Survival was somewhat more successful after fall burning at the lower elevations.

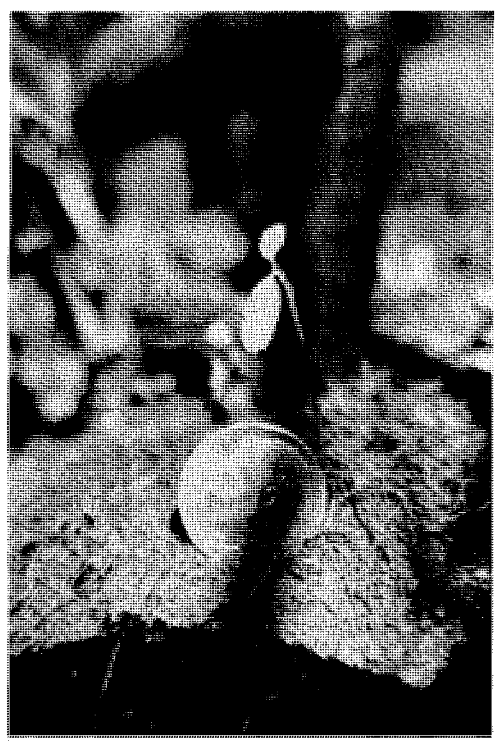

Fig. 6. Three-month old redstem seedling on the fall burn at Placer Creek, August 1, 1972. Seedling is typical of those growing under dense herbaceous vegetation.

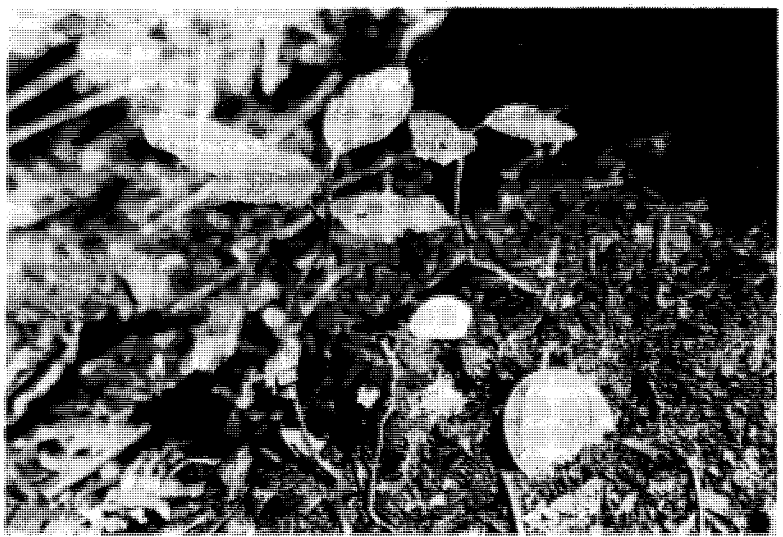

Fig. 7. Three-month old redstem seedlings on the fall burn at Placer Creek, August 1, 1972. These seedlings were growing in full sunlight.

Fig. 8. Three-month old redstem seedlings on the fall burn at Placer Creek, Aug. 1, 1972. Seedlings show no signs of desiccation even though soil moisture is below the wilting point. This is typical of seedlings growing on the severe burn sites in full sunlight.

DISCUSSION

SEEDLING EMERGENCE

The ultimate number of new seedlings that appear after a prescribed burn depends on the quantity of seeds stored in the duff and soil, and the intensity of the heat applied to that seed.

Our fall burns always caused more seedlings to emerge than spring burns. Mutch (1974) documented greater quantities of redstem seedlings on more intense burns on an experimental wildfire in the White Cap study area in the Selway-Bitterroot Wilderness of northern Idaho. Biswell (1961) found the same effect with *Ceanothus* species when burning brushfields in California. The difference in fire intensity between spring and fall burning is probably responsible for the difference in seedling emergence. Hooker (1972) measured soil temperatures during spring burns in the Lochsa River drainage. Soil surface temperatures failed to reach 150°F at 23 percent of his pyrometer locations. Temperatures less than 250°F were found at 51 percent of his pyrometer locations. Heat treatment tests with redstem seeds have shown that germination declines at temperatures of 180°F and below, with optimum temperatures near 212°F (Glazebrook, 1941; Isaacson, personal communication).

During the spring burning period (April-May) soil moistures were usually high. In order for high soil temperatures to occur, heat from the burn had to first evaporate large amounts of moisture. Highest seedling densities on spring burns were associated with the more severe burn sites.

With fall burning, fire temperatures were hotter, soils were drier, and most of each burning site received an adequate heat treatment for seed germination. Consequently, seedlings were generally more evenly distributed on fall burns than on spring burns.

We did not encounter any evidence that prescribed burns were too hot and, therefore, a detriment to seed germination. Gratkowski (1962), working with seeds of *Ceanothus velutinus*, found that exposure of up to 40 minutes duration with dry heat (176-221°F) had no detrimental effect on germination percentage or seedling vitality.

Cronemiller (1959) documented that light burns in chapparal were unsuccessful in causing deerbrush (*Ceanothus integerrimus*) seedlings to emerge and establish. However, a severe burn produced 300,000 seedlings per acre. Cronemiller concluded that light burning had the effect of reducing deerbrush density, especially when it was done repeatedly.

Almost 100 percent of the new seedlings emerge the spring following the burning treatment; however, we found that new seedlings appeared for a number of years following both spring and fall prescribed burning. Cronemiller (1959) also noted that a small amount of germination of deerbrush occurred the second and third years following a burn. Rarely did he find seeds germinating after the sixth year. On Holly Creek we documented additional seed germination for 8 years following the prescribed burn. One reason for this continuing germination is probably the increased capacity of the surface soil to absorb heat following burning. Surface soil temperatures were 20-40°F higher on burned plots than control plots following spring burning (Hooker 1972). Pearce and Wooley (1936) found higher soil temperatures for 5 years after a burn in North Carolina, as compared to an unburned area. Pengelly (1966) indicates that redstem seeds exposed to insolation alone will germinate, and we have also observed this.

This continued germination for several years following a burn could occasionally increase seedling establishment. On Holly Creek, 96 percent of the seedlings emerged in the spring of 1967; however, mortality was extremely high because the summer of 1967 was very dry. The few new seedlings which emerged in the spring of 1968 survived much better, because of the unusually wet conditions that summer, and new plants were added to the brushfield community.

Seedling Growth

Sampson (1944), Vlamis and Gowans (1961), Mayland (1967), Schultz et al. (1958), Wagle and Kitchen (1971), Hooker (1972), Ahlgren (1963), and others have documented higher nitrogen levels and increased availability of nitrogen for plant growth following burning. Our studies have shown that nitrate nitrogen levels increased as burn intensities increased. Ammonium nitrogen also increased following burning. Vlamis et al. (1955) also correlated increases in the nitrogen supply with burn intensity and most of the increase occurred the first year or two following treatment. Wagle and Kitchen (1971) found higher nitrogen content in the top 15 cm of soil in a 3 year old burn, but this effect was not apparent in low intensity burns.

In the field, we found that seedling growth was best on the more intensely burned areas—those which had been burned in the fall. Whether or not the seedling growth was due to the nitrogen levels is speculative. Growth of wedgeleaf (*Ceanothus cuneatus*) and deerbrush ceanothus seedlings has been correlated with the increased availability of nitrogen following burning (Schultz et al. 1958). Schultz also found that deerbrush seedlings responded to added nitrogen with vigorous growth during the first growing season, and plants with root nodules outgrew plants without root nodules by a large margin. Vlamis et al. (1958) and Snyder (1925) found that nodulated ceanothus plants had more nitrogen in their tissues than plants without nodules.

There are factors affecting seedling growth rates other than nitrogen availability. This was demonstrated when we grew seedlings in controlled growth chambers using the same soil from the field. In these tests, growth rates were opposite those obtained in the field. Therefore, we speculate that the nutrient availability on spring-burn soils is adequate for good seedling growth and that there are other limiting factors affecting seedling growth in the field.

Most redstem seedlings emerged in the spring following burning treatment. This means other vegetation has one entire growing season to become established after spring burning before the redstem seedlings emerge. Hooker (1972) describes the fast recovery on spring burn sites: "Rate of vegetative recovery was rapid on Holly Creek burn sites. Slopes burned early in the spring were well protected by vegetation before the next wet season." Hooker also states that bracken fern, thimbleberry and dogbane attained 90 percent of their maximum growth within the first 60 days after spring burning.

Redstem seedlings growing under heavy shade are very small and spindly. Many seedlings on spring burns emerge under dense canopies of timbleberry and bracken fern. Phares (1970), studying growth of red oak seedlings in relation to light and nutrients, found that under low light intensities seedlings were not able to utilize all of the nutrients that were available to them. Mueggler (1965), and Hickey and Leege (1970), noted that redstem has affinities for areas of thin canopies (0-25% crown cover) and a low tolerance of shade.

Conditions for seedling growth are much better after fall burns. Vegetation does not establish until the following spring and redstem seedlings are among the first plants to emerge. They do not have to compete for light, nutrients and moisture with plants already there.

We did not find a relationship between soil moisture and seedling growth. However, available soil moisture and seedling growth are both affected by competing vegetation. Fergusen (1971), working with bitterbrush seedling establishment, found that when he eliminated competing vegetation, seedlings were able to obtain sufficient water from the soil to continue growth throughout the summer. On the Placer Creek spring burn, 90 percent of all seedling growth occurred by the end of June. On the Placer Creek fall burns, 71 percent of all seedling growth had occurred by the end of June. Soil moisture was not significantly different between the spring or fall burns, but perhaps competition for that soil moisture was different. Kramer (1969) states that the absorbtive capacity of newly emerged radicles and rudimentary root systems of young seedlings is much lower than for older plants. It has been shown repeatedly that what might be taken for suppression by shading is actually unequal competition for soil moisture (Shubert, 1969).

Seedling Establishment

Competition with herbaceous vegetation seems to be a key factor affecting the establishment of many shrub seedlings. Biswell and Gilman (1961) found that herbaceous areas of the Tehama winter range in California produced numerous shrub seedlings when burned, but that most of the seedlings died as a result of competition. Gibbens and Pieper (1962) fertilized seedlings of wedgeleaf ceanothus. The fertilizer caused an increased growth of herbaceous plants and this was the biggest factor causing wedgeleaf seedling mortality. It has already been noted that redstem seedlings which emerge on spring burns compete with plants that are well established with a full growing season behind them.

Successful seedling establishment usually depends on seedling survival through the first summer. Sampson (1944) found that 60 percent of the brush seedlings that survived the first summer were alive 5 years after burning. However, we found that only 9 percent of the redstem seedlings that survived their first summer became established in the plant community; 89 percent of the seedlings alive at the end of their first summer died during their first winter.

We were not able to document the cause for this high winter mortality, but there are several possibilities. Some of the seedlings counted as alive at the end of the summer could have been past the point of recovering from the dry summer conditions. Frost heaving is an important factor affecting lodgepole pine seedling establishment (Cochran, 1973), and could also be a factor with redstem. Cold winter temperatures at a period when snow is absent, especially when following a warm period, may cause seedling losses as it sometimes causes dieback in older redstem plants. Rodents could also use new seedlings for food during the winter months. Stout et al. (1971) documented bark peeling by rodents on *Ceanothus* species following a wildfire in northern Idaho.

We have found that successful redstem establishment depends on seedling survival through the first 12 months. Eighty-two percent of the 12-month old seedlings became established in the plant community.

SUMMARY AND CONCLUSIONS

Large wildfires in the early 1900's burned over many of the low elevation forests in northern Idaho. Seral plant communities of grasses, forbs, and shrubs followed these wildfires and created important big game winter ranges. Redstem ceanothus is an important browse plant on these ranges.

Due to natural plant succession, redstem has been declining within these plant communities. In 1965, the Idaho Fish and Game Department began a study on the use of prescribed burning to rejuvenate the seral plant communities. This paper reports the findings from that portion of the investigation relating to redstem emergence and survival following both spring and fall burning.

Information was gathered from study areas on five different tributaries of the Lochsa River in north-central Idaho over an 8 year period.

Prescribed burning was done in the spring during the months of April and May, and in September and October after fall rains reduced wildfire danger.

Both spring and fall burns were successful in causing redstem seeds to germinate. However, seedlings were more numerous after fall burning with an average of 186,000 seedlings, compared with 47,000 per acre on spring-burned areas.

Best seedling growth occurred on fall burns. Seedlings which emerged on fall burns continued growing through August while seedlings on spring burns had nearly terminated growth by the end of June. Competition with other vegetation for light, water, and nutrients appeared to be the key factor causing differences in seedling growth and vigor between spring and fall burns. Vegetation establishes immediately after spring burns, however, redstem seedlings do not emerge until the following spring. This means they must compete with vegetation that has a one-growing season head start. Conversely, vegetation does not establish after a fall burn until the following spring, the same time that redstem seedlings emerge.

Seedling survival was related to summer precipitation, aspect, elevation, and type of burn (fall vs. spring). Above normal precipitation in July and/or August improved seedling survival. Survival was poorest on south and southwest aspects. Survival was higher at 3,000 feet elevation than at 2,000 feet. Survival was better on fall burns than spring burns.

MANAGEMENT RECOMMENDATIONS

The future of northern Idaho elk herds is dependent upon adequate winter food supplies. Therefore, it is crucial that seral shrub communities on key winter ranges be enhanced for browse production and maintained in that condition. On many areas, redstem has declined, and the land manager's major objective should be to establish new plants on these sites.

Emergence, growth, and survival of redstem seedlings were better following fall burning. Neither spring nor fall burning guaranteed that new redstem plants would establish because exceptionally dry summers were successful in eliminating almost all of the newly emerged seedlings. However, fall burning did substantially increase the chances of redstem establishment and therefore, we highly recommend it for winter ranges in need of redstem plants.

As hotter fires produced the best results, we recommend that fall burning be done after early frost has cured the herbaceous fuels and before fall rains have saturated the ground and fuels. Temperatures should be above 70° and humidities below 30 percent. If shrubs and trees are slashed first so that more fuels are close to the ground, fires can be conducted at lower temperatures and higher humidities. Slashing is an expensive treatment, but it increases the heat near the ground where it is needed for treating the redstem seed, and it de-

Table 10. Common and botanical names of plants mentioned in text, listed alphabetically by common name.

Bitter brush	*Purshia tridentata*
Bitter cherry	*Prunus emarginata*
Cascara	*Rhamnus purshiana*
Deerbrush	*Ceanothus integerrimus*
Dogbane	*Apocynum androsaemifolium*
Douglas fir	*Pseudotsuga menziesii*
Grand fir	*Abies grandis*
Huckleberry	*Vaccinium membranaceum*
Lodgepole pine	*Pinus contorta*
Mountain lover	*Pachistima myrsinites*
Mountain maple	*Acer glabrum*
Ninebark	*Physocarpus malvaceus*
Ocean spray	*Holodiscus discolor*
Pachistima	*Pachistima myrsinites*
Pacific dogwood	*Cornus nuttallii*
Ponderosa pine	*Pinus ponderosa*
Red oak	*Quercus rubra*
Red Osier dogwood	*Cornus stolonifera*
Red twin-berry	*Lonicera utahensis*
Redstem	*Ceanothus sanguineus*
Serviceberry	*Amelanchier alnifolia*
Snowberry	*Symphoricarpos albus*
Snowbrush	*Ceanothus velutinus*
Syringa	*Philadelphus lewisii*
Thimbleberry	*Rubus parviflorus*
Wedgeleaf	*Ceanothus cuneatus*
Western red cedar	*Thuja plicata*
White spiraea	*Spiraea betulifolia*
Willow	*Salix scouleriana*

creases fire control costs because burning can be done when the surrounding standing vegetation is difficult to burn.

We did have some success in getting redstem seedlings established with spring burns at the higher elevations and on east and west aspects. Consequently, some benefits, albeit inferior to fall burning, can be expected when spring burning is used in those areas.

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