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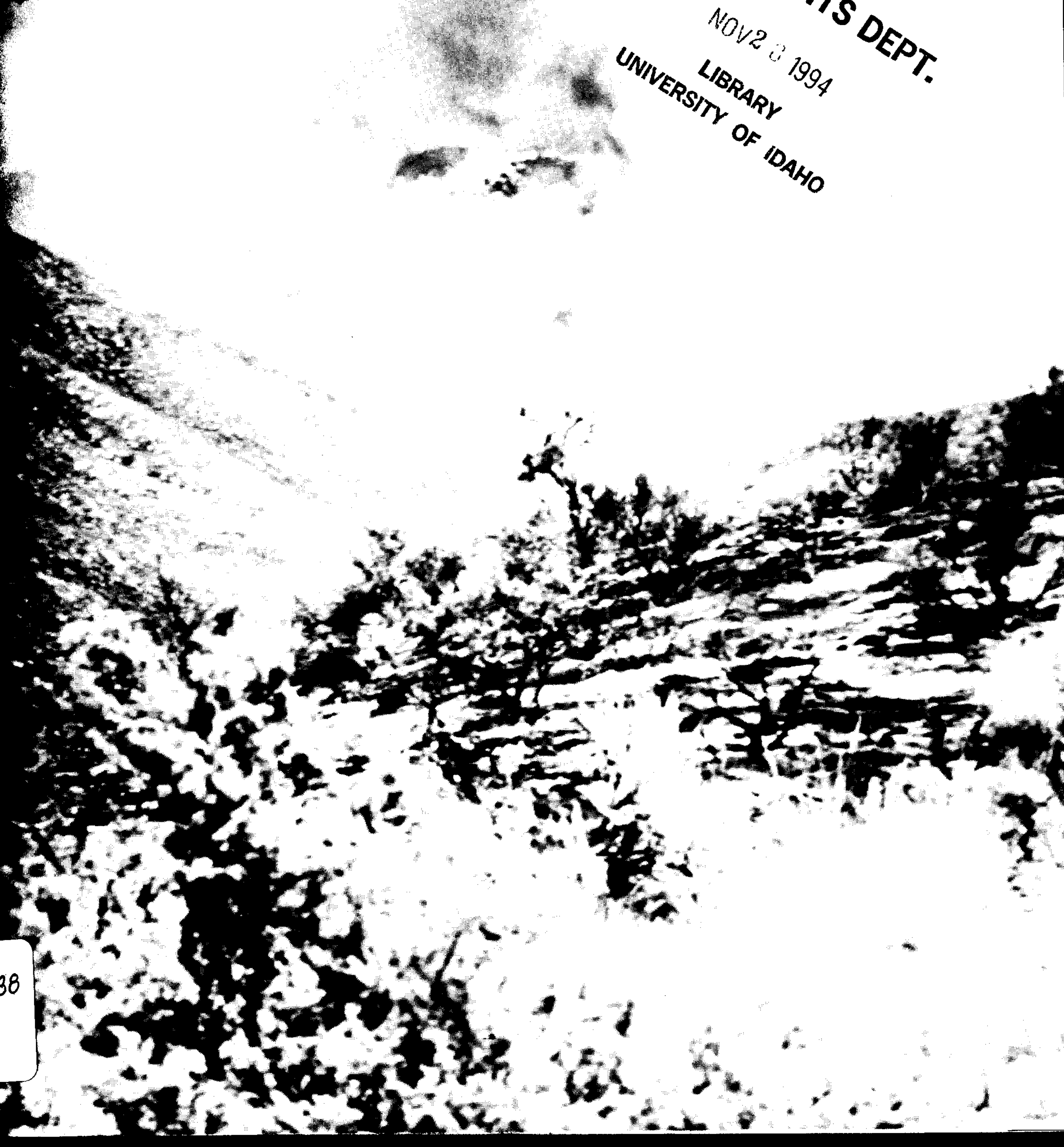

FACTORS INFLUENCING POSTFIRE SAGEBRUSH REGENERATION IN SOUTH-CENTRAL IDAHO

Mike Boltz

ABSTRACT

Sagebrush seedling establishment appeared to be strongly related to moisture availability as influenced by ecological site, soil surface texture, herbaceous competition, microtopography, seedling year precipitation, exposure, position on slope, etc. Many of the same factors influence seed source availability following wildfire and likelihood of reburn prior to maturity. Compaction planting methods show promise for enhancing seedling establishment.

INTRODUCTION

Like many portions of the Intermountain region, the Jarbidge Resource Area (JRA) of the Boise District, Idaho, Bureau of Land Management (BLM), has experienced a major vegetation conversion from big sagebrush (*Artemisia tridentata*) communities to herbaceous communities. Since 1973, wildfires have converted over 740,000 acres of the 1,690,473 acres of public land within the JRA from shrub to herbaceous vegetation. From 1971 to 1986, over 9 percent of the previously burned areas reburned, with additional large reburns in 1987. About 343,000 acres were reseeded for Emergency Fire Rehabilitation (EFR) during this period, primarily to herbaceous species. Some shrubs, particularly fourwing saltbush (*Atriplex canescens*), were included in these seed mixes, but generally did not establish in sufficient densities to mitigate the ongoing shrub loss. Large fires and accelerated fire frequencies in previously burned areas suggested that natural redevelopment of sagebrush communities on burned lands might not meet Jarbidge Resource Management Plan wildlife habitat objectives. Large-scale loss of shrub habitats and attendant public controversy regarding land treatment proposals in the Jarbidge Resource Management Plan prompted a 1987 reevaluation of JRA EFR practices as a component of the Jarbidge Sagebrush Management Plan. The Jarbidge Sagebrush Management Plan, consisting of a Normal Fire Rehabilitation Plan and a Greenstripping Plan, was designed to maintain sagebrush communities on newly burned sites and reduce the rate of conversion to herbaceous communities by fire.

To evaluate the need for large-scale replanting of big sagebrush, it was necessary to assess the natural regeneration potential of big sagebrush within the JRA. A 1985 attempt to use bioassay of soil samples from a recently burned area did not provide a reliable indication of sagebrush regeneration potential. Consequently, ecological site-based predictors were developed based on observed responses following fires to assess the need for inclusion of big sagebrush in EFR seed mixes. Degree of annual infestation, soil and climatic conditions, and the influence of reburns were also examined. Sagebrush reinvasion following fires was compared to that following other types of sagebrush control treatments to evaluate the premise that sagebrush would reinvade large burns as reliably as on other types of treatments.

In 1986, duplicate big sagebrush planting trials were established at two sites representative of the major ecological sites that are most vulnerable to wildfires. The trials were established by the Boise District in conjunction with Steve Monsen of the Forest Service, Intermountain Research Station, Shrub Sciences Lab and Marshall Haferkamp of the Agricultural Research Service. Evaluation of the trials was completed at the Shrub Sciences Lab. The results of these trials were integrated with the site-based predictors and the Jarbidge Resource Management Plan objectives in developing the EFR prescriptions in the Jarbidge Sagebrush Management Plan.

The 1986 trials indicated that standard reseeding equipment (drills) would not dispense big sagebrush seeds consistently at an adequate rate due to inadequate agitation, small aperture size, and seed tube blockage. At that time, results of the few aerial applications had been poor or were difficult to differentiate from natural regeneration. The 1986 trials also suggested that sagebrush establishment was enhanced by cultipacking into the soil surface. Consequently, the Boise District developed a sagebrush seeder that incorporated a fertilizer spreader, anchor chain or tire drags, and a vine-roller cultipacker.

STUDY AREA AND METHODS

The Jarbidge Resource Area is located in south-central Idaho in Elmore, Owyhee, and Twin Falls Counties. The JRA is subdivided into a number of historic grazing administrative units, such as the Saylor Creek Unit. The majority of the JRA is located south of the Snake River between the Bruneau River, Salmon Falls Creek, and the Humboldt National Forest boundary to the south in Nevada, with a smaller portion located north of the Snake River between King Hill and Bennett Creeks. The plant communities and associated ecological sites within the JRA are shown in table 1.

Salt desert shrub (SDS) communities, which include the shadscale (*Atriplex confertifolia*), winterfat (*Ceratoides*

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Table 1—Plant communities and associated ecological sites in the Jarbidge Resource Area. Site abbreviations are used in the figures in this paper. Other abbreviations used in the figures are defined in text

Plant community	Ecological site	Abbreviation
Shadscale/Indian ricegrass	Calcareous Loam 7-10	CL7-10
Winterfat/Indian ricegrass	Silty 7-10	S7-10
Nuttall saltbush/Indian ricegrass	Saline Silty 7-10	SS7-10
Greasewood/basin wildrye	Saline Bottom 8-12	SB8-12
Wyoming big sagebrush/Thurber needlegrass	Saline Upland 7-12	SU7-12
Basin big sagebrush/Indian ricegrass	Sand 8-12	S8-12
Wyoming big sagebrush/Indian ricegrass	Sandy Loam 8-12	SL8-12
Wyoming big sagebrush/Sandberg bluegrass	Loamy 7-10	L7-10
Wyoming big sagebrush/Thurber needlegrass	Loamy 8-10	L8-10
Wyoming big sagebrush/bluebunch wheatgrass	Stony Loam 8-12	SL8-12
Wyoming big sagebrush/bluebunch wheatgrass	Loamy 10-12	L10-12
Wyoming big sagebrush/bluebunch wheatgrass	Loamy 10-13	L10-13
Mountain big sagebrush/bluebunch wheatgrass	Loamy 12-16	L12-16
Mountain big sagebrush/bluebunch wheatgrass	South Slope 12-16	SS12-16
Basin big sagebrush/basin wildrye	Loamy Bottom 12-16	LB12-16
Basin big sagebrush/Idaho fescue	Loamy Upland 12-16	LU12-16
Black sagebrush/bluebunch wheatgrass	Shallow Calcareous Loam 10-16	SCL10-16
Low sagebrush/Idaho fescue	Shallow Claypan 12-16	SC12-16
Mountain big sagebrush/bluebunch-fescue	Loamy 13-16	L13-16
Mountain big sagebrush/Idaho fescue	Loamy 16+	L16+

lanata), Nuttall saltbush (*Atriplex nuttallii*), and greasewood (*Sarcobatus vermiculatus*) communities, comprise only a small portion of the JRA, and are localized on the Bruneau Arm and along the Snake River Canyon. The low (*Artemisia arbuscula*), black (*Artemisia nova*), and mountain big (*Artemisia tridentata* ssp. *vaseyana*) sagebrush communities occur at higher elevations on Bennett Mountain and near the Nevada border.

Each Site Writeup Area (SWA) defined by the 1981-83 inventory was classified into present plant communities based on the overstory and understory dominants based on composition by weight. SWA's normally include only one seral community of one ecological condition class of one ecological site. However, some SWA's are complexes of single seral plant community/condition class/ecological site units. Seedings were classified by the composition by weight of annual grasses and seeded species. Vegetation that was predominantly cheatgrass (*Bromus tectorum*) or medusahead (*Taeniatherum asperum*) was classified as annual communities.

The ecological site classification was plotted on a half inch per mile scale base map and overlays of the present plant communities (1981-83), post-1971 fires, and land treatment projects were prepared. The project/fire segment was the sampling unit for evaluating (1) frequency of sagebrush reinvasion, (2) percent reburn, and (3) percent shrub survival within exterior fire and/or land treatment project boundaries. Each project/fire segment included (1) only one ecological site or complex of ecological sites, (2) only one uniform pretreatment community, (3) only one uniform sagebrush control or reseeding treatment, which was applied at only one point in time, and (4) only one posttreatment plant community or plant community complex (SWA). The boundaries of these project/fire segments were determined by the overlap of the fire, project, and plant community overlays and the base map so that the conditions were met simultaneously.

The plant communities from the 1963 Saylor Creek Unit inventory were plotted on a half inch per mile scale overlay to evaluate the conversion of sagebrush to herbaceous vegetation between 1963 and 1981. The Saylor Creek Unit has had the most extensive sagebrush losses to wildfire in the JRA and therefore lends itself to analysis of landscape changes through wildfire. The location, extent, and dominant species composition of the plant communities were contrasted for the 1963 and 1981 overlays. All other old (1955-65) inventory plats were compared with the JRA fire map, project files, and the 1981-83 inventory overlay to determine the extent of wildfires and dominant species composition of prefire communities in other administrative units prior to 1971. Comparison of this information indicated that there were few major range fires prior to 1971 in all administrative units except Saylor Creek. Most fires that did occur prior to 1971 in the other administrative units were documented by project files. The widespread conversion of sagebrush to herbaceous vegetation in the other administrative units after 1971 could therefore be evaluated without significant bias. (No fire maps were made prior to 1971.)

The area of mature shrub communities surviving each fire expressed as a percentage of the total area within exterior fire boundaries was determined from: (1) previous calculations by the inventory within burned SWA's; (2) digitizer measurements of the overlays for each ecological site within fire boundaries; or (3) ocular estimates of relative cover on the overlays for each ecological site within fire boundaries.

The post-1963 and post-1971 reburn statistics were derived from an overlay of fire frequency for fires between 1971 and 1985. The percent reburn for all areas burned prior to 1963 was estimated ocularly as a percent of the total area within exterior fire boundaries for each post-1971 fire within the Saylor Creek Unit. Ocular estimates were based upon the midpoints of three cover classes (0-25 percent, 26-75 percent, 76-100 percent), 0, and 100 percent. Evidence of burning prior to 1963 was provided by dominance of nonseeded herbaceous vegetation or by project records. The percent reburn since 1971 for each post-1971 fire in the entire JRA was determined in a similar manner. The database includes all fires after 1971 but prior to the time a given site was inventoried between 1981 and 1983.

Percent reburn, percent shrub survival, fire acreages from the Boise District fire records, and dominant species composition of prefire communities were used to estimate acreage converted from shrub to herbaceous vegetation by each fire. The Site Writeups (descriptions of seral community floristic composition by weight) were used to determine sagebrush composition by weight for each burned, plowed, sprayed, or chained SWA. Personal knowledge also tempered evaluation of sagebrush reinvasion based solely on the Site Writeups, particularly for projects that were relatively new at the time of the inventory.

The 1986 planting trials were conducted on previously sagebrush-dominated sites near Wintercamp (Crows Nest) and Three Creek Well in Owyhee County, ID, which had initially burned in 1985. Crows Nest, a Loamy 8-10 site on Purdam-Power-Elijah silt loams (Noe 1991), was previously in poor ecological condition. Three Creek Well, a Loamy 10-13 site on Heckison-Big Flat-Inside Desert silt loams (Harkness 1992), was previously in fair to good ecological condition. Both sites were reburned with a propane field flamer to control cheatgrass competition, recreate newly burned conditions, and facilitate identification of planted sagebrush seedlings. This was done at Crows Nest in May 1986 and at Three Creek Well in September 1986. Half of each of the two sites was disked by a disk-chain to compare burned/plowed and burned pretreatments. The replicated planting treatments were: broadcast/anchor chained, disk-chained/broadcast, broadcast/imprinted, cultipack seeder, rangeland drill, and broadcast without coverage. In November 1986, Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) and Nordan crested wheatgrass (*Agropyron desertorum*) were planted at average rates as shown in table 2.

Table 2—Average seeding rates at Crows Nest and Three Creek Well sites

Study site	Low rate Artrw(PLS)	Low rate Agde	High rate Artrw(PLS)	High rate Agde
	Lb/acre			
Crows Nest	0.38	13.96	1.18	9.36
Three Creek Well	.58	21.42	1.14	11.16

Every effort was made to dispense the seed at equivalent rates with all reseeding equipment. Soil conditions were moist to wet at planting at Three Creek Well and moist to surface dry at Crows Nest. These trials applied variable treatments to relatively uniform sites. Cheatgrass cover and frequency and density of seeded and native species were measured in 40 randomly placed one square meter quadrats in each replication (two per site) of each treatment at both sites. Measurements were made in May 1987.

The Poison Springs, Solosabal, and Pothole Reservoir sites are located near Glenns Ferry, ID. They were previously sagebrush-dominated, but all burned initially in June 1987. Poison Springs is a Loamy 10-12 site on Trosi-Chilcott-Tenmile gravelly loams; Solosabal is a Loamy 8-10 site on Owsel-Purdam silt loams (with inclusions of Sandy Loam 8-12 on Xeric Torriorthents); Pothole Reservoir is a Loamy 8-10 site on Colthorp-Chilcott-Elijah-Purdam-Scism silt loams (Noe 1991). All three sites were previously in poor ecological condition. In December 1987 and January 1988, mixed Wyoming, mountain, and basin (*Artemisia tridentata* ssp. *tridentata*) big sagebrush seed lots were applied at the Poison Springs site and mixed basin and Wyoming big sagebrush seed lots were applied at the Solosabal and Pothole Reservoir sites. All seed lots were sold as Wyoming big sagebrush, but were contaminated with other subspecies. The overall application rate was 6.2 lb/acre bulk (0.7 lb PLS/acre). The sagebrush was applied directly with the Jarbidge Sagebrush Seeder (anchor chain drag) to moist or frozen seedbeds that had been drilled earlier under dry conditions. These plantings applied a relatively uniform treatment to varied microsites.

The Solosabal and Poison Springs sites were intensively evaluated in June 1988. Five 50-m transects were established at each of three subareas at the two sites. Understory and seeded species were rated by frequency, density, and percent ground cover in 30 1-square-meter plots along the first 10-m, third 10-m, and fifth 10-m intervals of each 50-m transect. Sagebrush seedling density was measured using a rating system to expedite counting of individuals. Consequently, the estimated densities may be higher than the actual densities.

Studies on plowed greenstrips used a 100-foot baseline transect running parallel to the seeding treatment. One 50-foot-long belt was randomly selected and permanently marked within each 20-foot interval along the baseline, running at a 45-degree angle to the baseline. Nested plot frequency and plot density were sampled at 5-foot intervals along the belts within a 50- by 50-cm nested plot frequency frame. Point cover was sampled on the four tips of the frame. Finally, densities of shrubs were counted in five 1/100-acre plots.

Statistical analysis included complete factorial analysis for sagebrush seedling densities, and ANOVA for 1986 trial seeding rates and sagebrush survival among ecological sites. Frequency of sagebrush reinvasion by ecological site, control treatment, and pretreatment vegetation and sagebrush seedling frequency by plot were analyzed by chi-square tests of independence.

RESULTS AND DISCUSSION

The average yearly reburn rate of previous fires for each major ecological site or similar group of sites is shown in figure 1. The percent reburn was estimated for

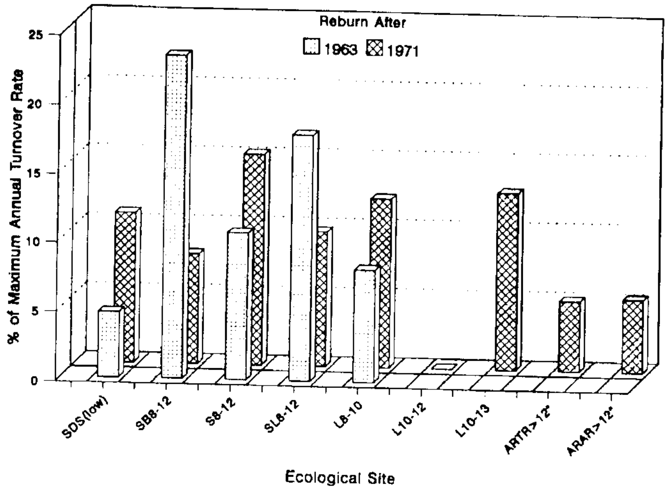

Figure 1—Average reburn of previous fires in the JRA as a percent of the maximum annual turnover rate (6.67 percent) for replacement of mature sagebrush stands in 15 years. Abbreviations for ecological sites are as shown in table 1 and in the text.

each fire as a whole rather than independently for each included ecological site within exterior fire boundaries. However, only fires that included the ecological site in question were included in the average. Although there is considerable separation among ecological sites among geographical groups of fires, the lack of independence in the data among ecological sites does not permit statistical analysis. The ecological sites are arranged in the approximate relative order of moisture availability and phenological development considering soil depth, texture, and precipitation zone. Both factors influence both the length of the fire season and the pattern of burning, which, in turn, influence probability of reburn and amount of sagebrush survival as islands and as individuals. The average yearly reburn rate shown in figure 1 is calculated as a percentage of 6.67 percent to compare the different time periods and magnitude of reburn. An annual reburn rate of 6.67 percent of a given area assuming no overlap of successive reburns would completely reburn the area by the end of 15 years. Since it takes a minimum of 15 years to redevelop a mature stand of sagebrush, a reburn rate much over 6.67 percent would probably prevent mature stands from redeveloping even if seedling establishment occurred.

In the Saylor Creek Unit, the average yearly reburn rate between 1963 and 1981 apparently differed among ecological sites. The probability of reburn was higher on the Sandy Loam 8-12 and Saline Bottom 8-12 ecological sites. Shrub communities on these ecological sites and on the Sand 8-12 site were already highly disturbed and invaded by cheatgrass, and a relatively large portion of them had already burned in 1963. The probability of reburn was relatively low on salt desert shrub (SDS-low) sites, which occur primarily on steep slopes and broad, very coarse-soiled ridgetops and support less fine fuel than the other ecological sites (Noe 1991). These include Nuttall saltbush, winterfat, and shadscale communities. Few of these had burned prior to 1963. The Loamy 8-10 sites were less highly disturbed, and had experienced relatively few fires prior to 1963. None of the other ecological sites are found in the Saylor Creek Unit.

In the JRA as a whole, no strong differences were observed in the average yearly reburn rate among ecological sites from 1971 to the date of inventory. This partially reflects the lack of independence in the data in that many of the same large fires were included in the statistics for each ecological site in the 7- to 13-inch precipitation zone. However, the fire frequency overlay indicated that the probability of reburn tended to increase after initial conversion of large areas of sagebrush to herbaceous vegetation, and geographically separated reburn "hotspots" developed. This is somewhat evident for the SDS-low group of ecological sites, and the Sand 8-12, the Loamy 8-10, and the Loamy 10-13 ecological sites in figure 1.

The probability of reburn tends to be lower than average for mountain and basin big sagebrush sites (ARTR>12"), which receive over 12 inches of annual precipitation. The black and low sagebrush sites(ARAR>12") also have a lower than average probability of reburn. These low sagebrush and low-black sagebrush intergrade sites generally have low productivity, particularly of fine fuel (Harkness 1992; Noe 1991), and are in better ecological condition than lower precipitation ecological sites, with little cheatgrass invasion. The low incidence of reburn on the Loamy 10-12 site is attributed to the small area occupied by the site and the good road access and availability of fuel breaks where it occurs. In general, sagebrush regeneration potential based on reburn probability is relatively poor on the Sand 8-12, Sandy Loam 8-12, Loamy 8-10, and Loamy 10-13 ecological sites, and relatively good on low and big sagebrush sites that receive over 12 inches of annual precipitation.

The average percent of the area within fire boundaries occupied by unburned fingers and islands of mature sagebrush communities (black bars) or mature mixed big sagebrush/salt desert shrub communities (dotted bar) at inventory is shown in figure 2. Sparse fuels and broken topography tend to retard fire spread on most of the salt desert shrub (SDS) sites, and to promote patchy burning. The relatively low survival of mature sagebrush communities on the Sandy Loam and Sand ecological sites in the 8- to 12-inch precipitation zone reflects the same factors influencing the probability of reburn there; namely, low moisture availability, accelerated phenological maturity, and greater annual grass invasion. However, the higher incidence of reburn alone did not account for lower survival, as the majority of the initial burns in sagebrush on these two sites did not reburn prior to the inventory. The greater survival of sagebrush within fire boundaries on the Loamy 7-10, 8-10, and 10-13 ecological sites reflects less continuous fuels (less cheatgrass) (Whisenant 1990), a generally lower frequency of reburn, and a somewhat longer green period. Site conditions are somewhat cooler and moister, and the soils have higher available water capacity (AWC), lower permeability, or both (Harkness 1992; Noe 1991). The Loamy 10-12 site has a greater than average cheatgrass composition due to its location in a highly disturbed setting.

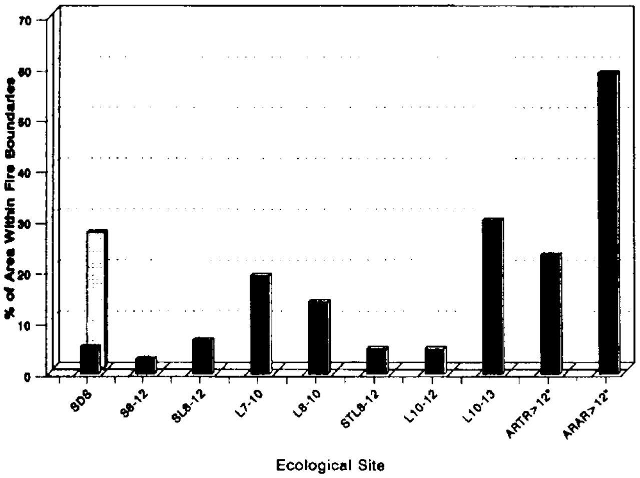

Figure 2—Average sagebrush survival as average percent of total area within exterior fire boundaries that was mature sagebrush at inventory. Abbreviations for ecological sites are as shown in table 1 and in the text. Means were significantly different ($F = 6.42^*$, $P = 0.00$).

Incidence of reburn was low on big and low/black sagebrush sites receiving over 12 inches of annual precipitation, except around Cedar Butte. Cheatgrass is relatively insignificant on these sites, which include the bulk of the fair or better ecological condition communities in the JRA. Survival of substantial areas of sagebrush within fire boundaries reflects the relatively long green period, less continuous fine fuels, and interspersion of the two types of ecological sites. The low/black sagebrush sites tend to serve as fuel breaks in all but the most extreme burning conditions.

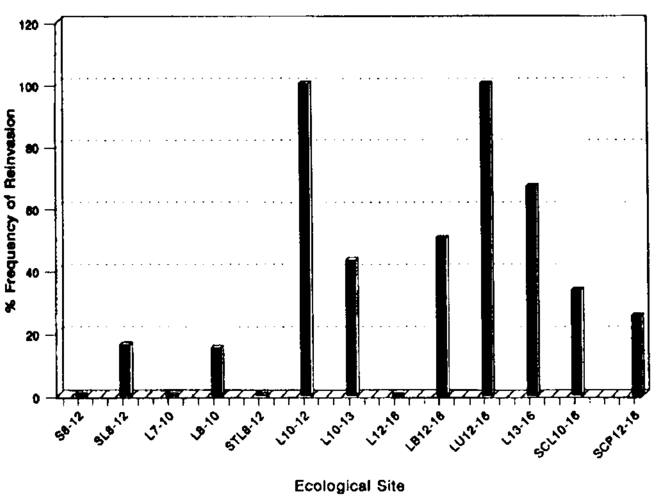

Figure 3—Frequency of occurrence of sagebrush composition exceeding 5 percent by weight for burned and reseeded project segments. All segments were previously sagebrush-dominated and did not reburn. Abbreviations for ecological sites are as shown in table 1. Frequencies were significantly different among sites ($\chi^2 = 22.74^*$, $P = 0.05$).

Figure 3 is based on the Site Writeups for burned and seeded project segments that did not reburn prior to the inventory. Sagebrush reinvasion/survival as individuals was considered absent for segments that lacked sagebrush or had less than 5 percent sagebrush composition by weight. Since the same Site Writeups were often used for both reburned and nonreburned communities, or reflected only the earliest stages of postfire succession, personal knowledge of the vegetation was also used to determine whether significant sagebrush reinvasion had occurred.

Natural sagebrush survival as individuals/reinvasion by seed was poorest on the driest sites, evidently reflecting more uniform burning and lower seed survival and availability (Bunting 1985; Young and Evans 1987), or harsher growing conditions for seedlings (Britton and Clark 1985). Poor interspersion of surviving sagebrush plants on cleanly burned areas further retards reinvasion by seed. Since the sandy big sagebrush sites have the lowest, most erratic precipitation, the lowest AWC, and most rapid surface soil permeability (Noe 1991), the availability of surface soil moisture is relatively brief and undependable. The loamy big sagebrush sites in the 7- to 10-inch precipitation zone also had a low frequency of survival/reinvasion in spite of more favorable soil/climatic characteristics. The loamy big sagebrush sites in the 10- to 13-inch and 12- to 16-inch precipitation zones and the low and black sagebrush sites in the 10- to 16-inch precipitation zone had a higher frequency of survival/reinvasion. These big sagebrush sites have a moderate to high AWC and moderately slow to slow permeability, while the low and black sagebrush sites have a very low to moderate AWC and slow permeability (Harkness 1992; Noe 1991). Surface soil moisture availability to seedlings is relatively dependable on these sites. This pattern is reasonable in light of the fact that big sagebrush seeds require saturation of the surface soil for germination (Weldon 1956).

Figure 4 is based on the frequency of occurrence of sagebrush composition by weight within the specified composition limits in Site Writeups for burned areas. The pattern is similar to figure 3, but excludes noninventory information and includes Site Writeup data for reburned areas and for both seeded and unseeded burns. There is no significant difference in the frequency of nonreinvasion of seeded and nonseeded burns by ecological site ($p = 0.05$). The drier ecological sites generally have less sagebrush survival/reinvasion on burned sites than the moister ecological sites, with the exceptions of the Saline Upland 7-12 and the Calcareous Loam 7-10 sites. Fires on these two ecological sites probably burned less completely due to low continuity and production of herbaceous fuels, and the sagebrush may represent plants that survived the fires. Big sagebrush survival/reinvasion comprising over 25 percent of total production was not observed on sandy sites, salt desert shrub sites, or loamy big sagebrush sites averaging below 9 inches of annual precipitation. Sagebrush must regenerate from soil seed reserves on sites without significant survival of mature plants (Johnson and Payne 1968; Mueggler 1956). The harsher the site conditions, the more unlikely is the establishment of adequate stands of shrubs from the soil seed reserves alone (Britton and Clark 1985).

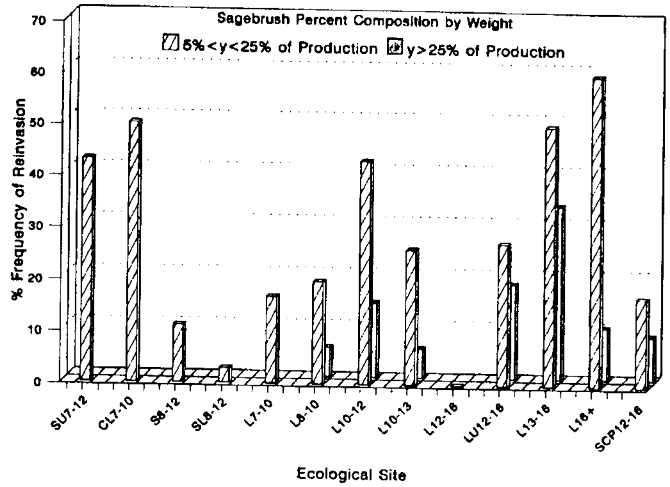

Figure 4—Frequency of occurrence of sagebrush composition by weight in specified composition classes from Site Writeups for burned areas, both seeded and unseeded. Abbreviations for ecological sites are as shown in table 1. Frequencies were significantly different among sites ($\chi^2 = 48.87^*$, $P = 0.05$).

Figure 5, like figure 3, represents burned and seeded project segments. Prefire sagebrush communities with predominantly bare ground or perennial grass understories were considered to have low cheatgrass levels, while prefire sagebrush communities with predominantly cheatgrass understories (particularly in the interspaces) were considered to have moderate cheatgrass levels. Previously burned or plowed areas dominated by cheatgrass and lacking a significant sagebrush overstory were considered to have high cheatgrass levels. The frequency of sagebrush reinvasion following fire was significantly higher for sagebrush communities with a minimal cheatgrass component than for sagebrush communities with a cheatgrass understory or for previously burned areas dominated by cheatgrass. This could reflect (1) cleaner burns and poor interspersion of surviving sagebrush plants due to more continuous fuels on infested sites, (2) a much greater number of safe sites on and slower cheatgrass occupation of previously uninfested burned communities, and (3) typically lower cheatgrass levels on ecological sites receiving over 10 inches of annual precipitation.

Figure 6, like figures 3 and 5, represents reseeding project segments that did not reburn. The sandy and loamy Wyoming big sagebrush sites in the 7- to 13-inch precipitation zone received most of these treatments. The burned treatment had significant (≥5 percent of composition by weight) sagebrush reinvasion significantly less often, while the plowed treatment had significant sagebrush reinvasion significantly more often than expected. Reinvasion on the chained and sprayed treatments was not significantly different from the expected. While the chained treatments (11 years), sprayed treatments (13 to 26 years), and plowed treatments (11 to 28 years) were considerably older than the burned treatments (1 to 26 years) at the time of the inventory, most of the burned treatments still lacked a detectable sagebrush component in 1987-89 (over 5 to 9 years after the fire). Project segments that developed a significant sagebrush component

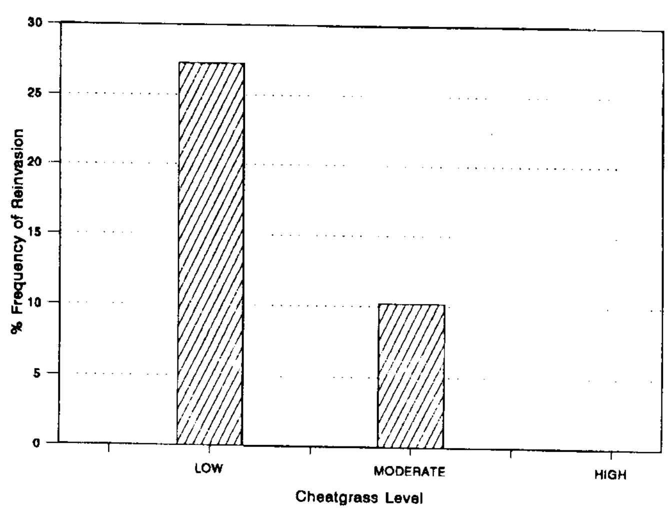

Figure 5—Frequency of occurrence of sagebrush composition exceeding 5 percent by weight for burned and reseeded project segments. All segments were previously sagebrush-dominated and did not reburn. Cheatgrass levels are defined in the text. Frequencies were significantly different among levels ($\chi^2 = 8.45^*$, $P = 0.05$).

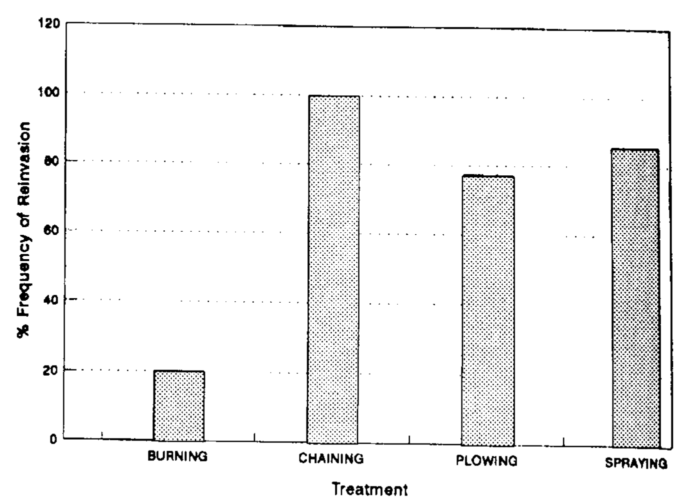

Figure 6—Frequency of occurrence of sagebrush composition exceeding 5 percent by weight for reseeded project segments. All segments were previously sagebrush-dominated and did not reburn. Frequencies were significantly different among sagebrush control treatments ($\chi^2 = 49.32^{**}$, $P = 0.05$).

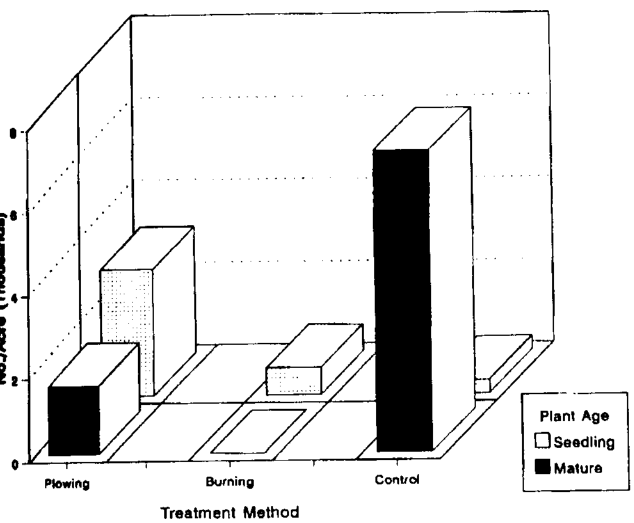

Figure 7—Average densities of mature and seedling Wyoming big sagebrush plants. Treatment means were significantly different ($F = 27.06^*$, $P = 0.00$) for mature plants and did not differ ($F = 0.75$, $P = 0.48$) significantly for seedlings.

after the inventory were classified as reinvaded based on these later inspections. The relatively low threshold (5 percent) used in the analysis also tended to minimize differences between treatment ages. Chaining, spraying, and plowing tend to have lower sagebrush mortality (Marquiss 1967; Taha 1972) and better interspersion of surviving plants than burning, and those control treatments or the subsequent reseeding operation may even plant whatever sagebrush seed is present, especially if done in the fall (Bleak and Miller 1955). The lack of a significant seed source on site during the first year after disturbance when the site is relatively open would appear to be a major factor retarding sagebrush reinvasion of treated sites (Bartolome and Heady 1978; Bunting 1985; Mueggler 1956).

Figure 7 shows mature and seedling big sagebrush densities on plowed/seeded, burned/seeded, and untreated Loamy 8-10 and Loamy 10-12 sites that had low and moderate cheatgrass levels prior to treatment. Figure 7 illustrates the differences in degree of sagebrush mortality and seedling density between plowed and burned treatments, even though seedling densities are not significantly different among treatments. These results support those shown in figure 6.

To sum up figures 1 through 7, burned big sagebrush sites receiving less than 10 inches of annual precipitation, particularly if the understory was cheatgrass-dominated, have an unsatisfactory probability of sufficient natural regeneration to restore prefire sagebrush cover and structure in a timely manner. This is due to: (1) inadequate soil seed reserves and poor survival of well-distributed mature plants to serve as a seed source; (2) the combined impacts of erratic and low precipitation, soil texture and depth, and herbaceous competition on moisture availability to sagebrush seeds and seedlings; and (3) higher loss of young sagebrush plants to subsequent reburns.

Figure 8 shows the results of the fall 1986 seeding trials at the Crows Nest study site (Loamy 8-10). Permeability was moderately slow to slow, and the AWC was moderate at both sites. The burned pretreatment resulted in very low levels (2.2 percent average cover) of cheatgrass competition during the seedling year. The disk-chained pretreatment and planting treatments tended to have higher cheatgrass cover (6.0 percent average cover), but neither level interfered with establishment of the seeded species. March and May 1987 each received slightly over 1 inch of moisture, but the 4.99 inches of precipitation received was only half of the average at the nearby Horse Butte weather station. It appears that the unusually low precipitation and the effects of the planting treatments themselves on seeding rate, planting depth, and seedbed moisture characteristics were responsible for the low and erratic densities of big sagebrush seedlings.

The low densities of sagebrush seedlings on the disk-chain and rangeland drill treatments could be partially explained by the significantly lower than average seeding rates achieved by these treatments ($p = 0.10$). Planting depths were probably more variable for the drill, disk-chain, and anchor chain treatments. The average planting depth was potentially greatest with the rangeland drill, since the other treatments used surface broadcasting. The relatively high soil disruption of the disk-chain treatment may have allowed deeper penetration/burial of part of the seed. The anchor chain coverage treatment also had the potential to bury at least some of the sagebrush seed rather deeply by dragging dirt over it under the dry surface soil conditions. These effects may have been magnified on the relatively

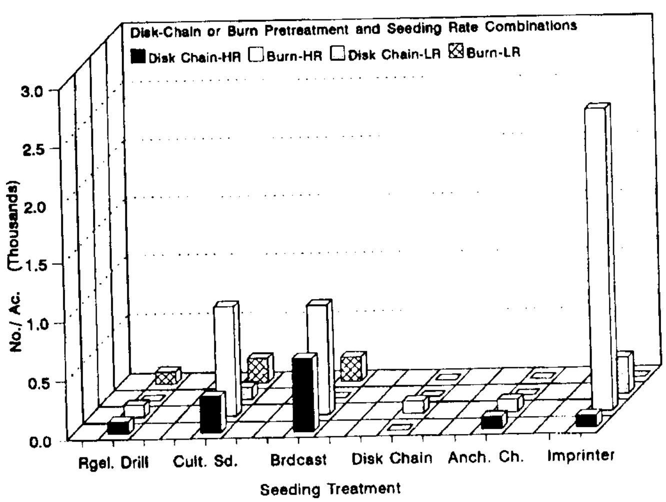

Figure 8—Average densities of Wyoming big sagebrush seedlings by seeding treatment, pretreatment, and seeding rate for fall 1986 at the Crows Nest site. The imprinter treatment mean was significantly higher than for other treatments, the burned pretreatment mean was significantly higher than the disk-chain pretreatment mean, and the high seeding rate (HR) mean was significantly higher than the low seeding rate (LR) mean ($p < 0.05$ for all). The seeding rate and pretreatment effects were primarily due to the imprinter treatment.

loose disk-chained pretreatment, particularly under relatively dry conditions during treatment. Big sagebrush seedlings emerge poorly from soil depths over one-fourth inch (Plummer and others 1968).

The broadcast only, anchor chain, and drill treatments relied in concept much more on overwinter settling to provide good soil-seed contact than did the cultipacker, imprinter, or disk-chain treatments. Soil moisture was adequate at treatment to allow formation of depressions by these compaction treatments, which helped store and concentrate the available moisture through the seedling year. The imprinter and cultipacker were especially effective on the burned pretreatment, which required less pressure for creation of stable depressions. In reality, the disk-chained seedbed was looser than that of the other two compaction treatments, and much of the seed fell behind the roller bar and did not receive compaction planting. Good soil-seed contact should promote germination by prolonging saturated soil conditions around the seeds. This should become more important as seedling-year precipitation declines or as surface soil permeability increases. Lack of seed coverage could hinder good soil-seed contact, but excessive planting depth could prevent emergence.

The broadcast-only treatment yielded substantial numbers of seedlings on both the burned and disk-chained pretreatments. The disk-chained pretreatment offered many depressions to trap the seed and concentrate the available moisture, and the relative looseness probably promoted seed coverage by overwinter sloughing. The majority of the seed broadcast on the burned pretreatment remained on the soil surface in absence of a coverage treatment. Some of it undoubtedly fell into soil cracks at planting or over the course of the dry winter. Moisture accumulation around playettes may have played a role in promoting germination.

Figure 9 shows the results of the fall 1986 seeding trials at the Three Creek Well study site (Loamy 10-13). The Wyoming big sagebrush seedling densities at this site were lower, the average cheatgrass cover was very low (0.5 percent), and competition from native perennial species was much higher than at Crows Nest. This site had been in better ecological condition and had higher site potential, resulting in much greater natural recovery of perennial herbaceous species than at Crows Nest. There were no significant differences between the disked and burned pretreatments, or the seeding rates, or among the planting treatments. However, the disk-chain pretreatment tended to have higher big sagebrush seedling densities, probably reflecting some reduction in herbaceous competition. This was particularly true for the broadcast-only treatment. The actual seeding rate for the drill and disk-chain treatments (low rate only) was significantly lower ($p = 0.10$) than for the other treatments. Few of the planted seedlings were in evidence the second year, probably because of excessive herbaceous competition. The results suggest that high herbaceous competition for moisture can offset the benefits of more favorable ecological site characteristics for sagebrush seedling establishment.

For the fall 1987 plantings, the Loamy 8-10 ecological site (Solosabal) had a considerably lower frequency of occurrence of big sagebrush seedlings than the Loamy 10-12 site (Poison Springs), but there was high variability

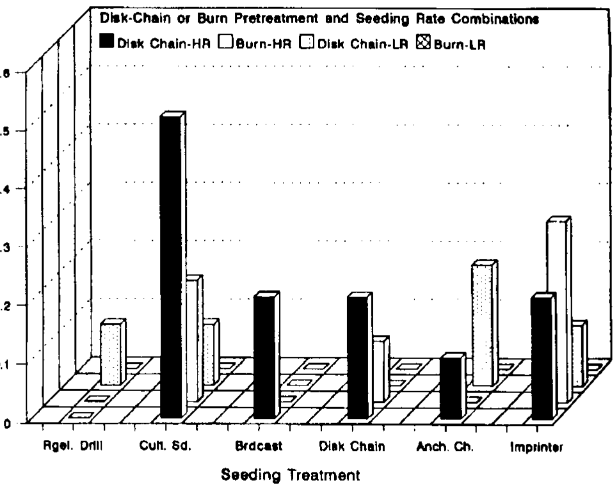

Figure 9—Average densities of Wyoming big sagebrush seedlings by seeding treatment, pretreatment, and seeding rate for fall 1986 plantings at the Three Creek Well site. There were no significant differences ($p < 0.05$) between disk-chain and burn pretreatments, seeding rates, or seeding treatments. Seeding rate abbreviations are the same as in figure 8.

among subareas at both locations (fig. 10). Precipitation was slightly above average for March, April, and May of the seedling year, but overall averaged only 78 percent of normal. The soils at the Loamy 8-10 site are deep and have a high AWC and moderately slow permeability, with the exception of Sandy Loam 8-12 inclusions on the steep

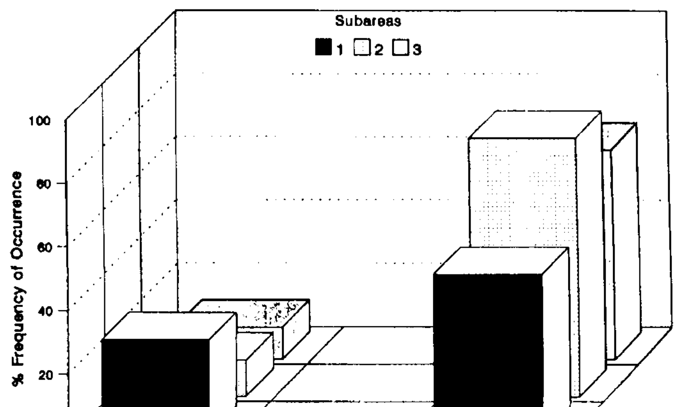

Figure 10—Frequency of occurrence of sagebrush seedlings by plot on two burned sites replanted in fall 1987 with the Jarbidge Sagebrush Seeder. Both sites were previously sagebrush-dominated. The 0.7-lb/acre PLS seeding rate was between the low and high seeding rates of the 1986 plantings. Frequencies by plot were significantly different among subareas ($\chi^2 = 29.66^*$, $P < 0.05$).

slopes (Noe 1991). The subarea with the highest seedling frequency on the Loamy 8-10 site was at the base of a northeasterly slope. The other two subareas were located on a level bench with a slight easterly slope and high on the steep northeasterly slope, respectively. Inclusions of the Sandy Loam 8-12 site with their lower AWC and moderately rapid permeability had few or no seedlings, as did well-drained ridgetops and southerly exposures of the Loamy 8-10 site. In some portions of the project, the only seedlings that established were in drainage channels. Seedling year cheatgrass cover was much higher (38.3 percent), but more typical of burned sites than at Crows Nest or Three Creek Well. Perennial cover averaged 7.8 percent. There was still no significant correlation between the numbers of big sagebrush seedlings and understory composition. Natural regeneration was absent.

The general exposure at the Loamy 10-12 site is to the southwest. Rock outcrops and stone nets are frequent, the topography is more broken, and the soils are shallower than on the Loamy 8-10 site. Many of the narrow ridgetops have a gravelly surface layer, which supports relatively little herbaceous growth. The gravelly areas are interspersed with pockets of loam, sandy loam, and sand surface texture. The AWC of the soils is low to moderate with slow to very slow permeability due to depth or surface texture (Noe 1991). The subarea with the highest seedling frequency was on a southwesterly ridgetop with a loamy surface soil well interspersed with gravelly loam and stone nets in the drainages. The subarea with the second-highest seedling frequency was in a pocket of loamy surface soil at the base of a northerly exposure. The other subarea was on a broad loamy ridgetop with few pockets of gravelly loam. Some plants also became established on gravelly ridgetops, on pockets of sandy soil, and even among the stone nets, but establishment was highly variable from place to place, even on the loamy soil type. Natural regeneration was minimal. Cheatgrass cover averaged 17.2 percent and perennial cover averaged 18.4 percent, but again, there was no significant correlation between numbers of big sagebrush seedlings and understory composition. This may reflect the depletion of perennials in poor-condition big sagebrush communities and temporary suppression of the annuals by the intensity of the fire. The greater variability in soils and habitats may have provided more “safe sites” than at the Loamy 8-10 site, in addition to the greater, more reliable precipitation. The Pothole Reservoir site did not receive enough seedling-year precipitation to allow full establishment and growth of the seeded species, including Wyoming big sagebrush.

The pattern of average seedling densities on the Loamy 8-10 and Loamy 10-12 sites corresponds exactly to that of the frequency of occurrence (fig. 11). Seedling densities were much higher on the 1987 plantings than on the 1986 plantings, reflecting a more normal level of precipitation and, apparently, favorable seedbed moisture characteristics and planting depth. The results tend to support the patterns of reinvasion in figures 3 and 4. On all but Area 1 at the Loamy 10-12 site, the wet soil was frozen to a shallow depth at application. Only the tops of the sidecast hummocks were dry enough to be easily moved by the anchor chain drag. This loose soil was available for covering

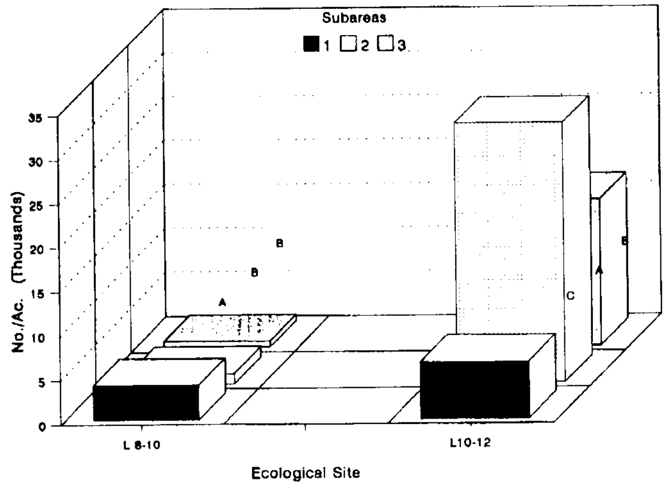

Figure 11—Average densities of sagebrush seedlings on two burned sites replanted in fall 1987 with the Jarbidge Sagebrush Seeder. Both sites were previously sagebrush-dominated. The 0.7-lb/acre PLS seeding rate was between the low and high seeding rates of the 1986 plantings. Mean densities with different letters at each site are significantly different ($P < 0.05$). Mean densities were not compared between sites.

the seed. The cultipacker firmed the loosened soil into a fairly level puddled surface with shallow furrows, which was stable during the seedling year. The seedbed resembled an imprinted seedbed, but with fewer, shallower, more widely spaced depressions. The furrows still concentrated the moisture, and seed-soil contact was probably good. It appeared that cultipacking enhanced the natural settling and puddling from overwinter precipitation, and that the anchor chain covered much of the seed. The Jarbidge Sagebrush Seeder apparently provided good coverage and firming for most soils under the planting conditions, except for the gravelly and stony areas, which had little loose soil from the drilling operation. It combined some of the best features of equipment used in the 1986 plantings. However, sagebrush seedling establishment still appeared to be strongly related to moisture availability as influenced by ecological site, soil surface texture, herbaceous competition, microtopography, seedling year precipitation, exposure, position on slope, and other factors, even when effective planting methods are used.

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