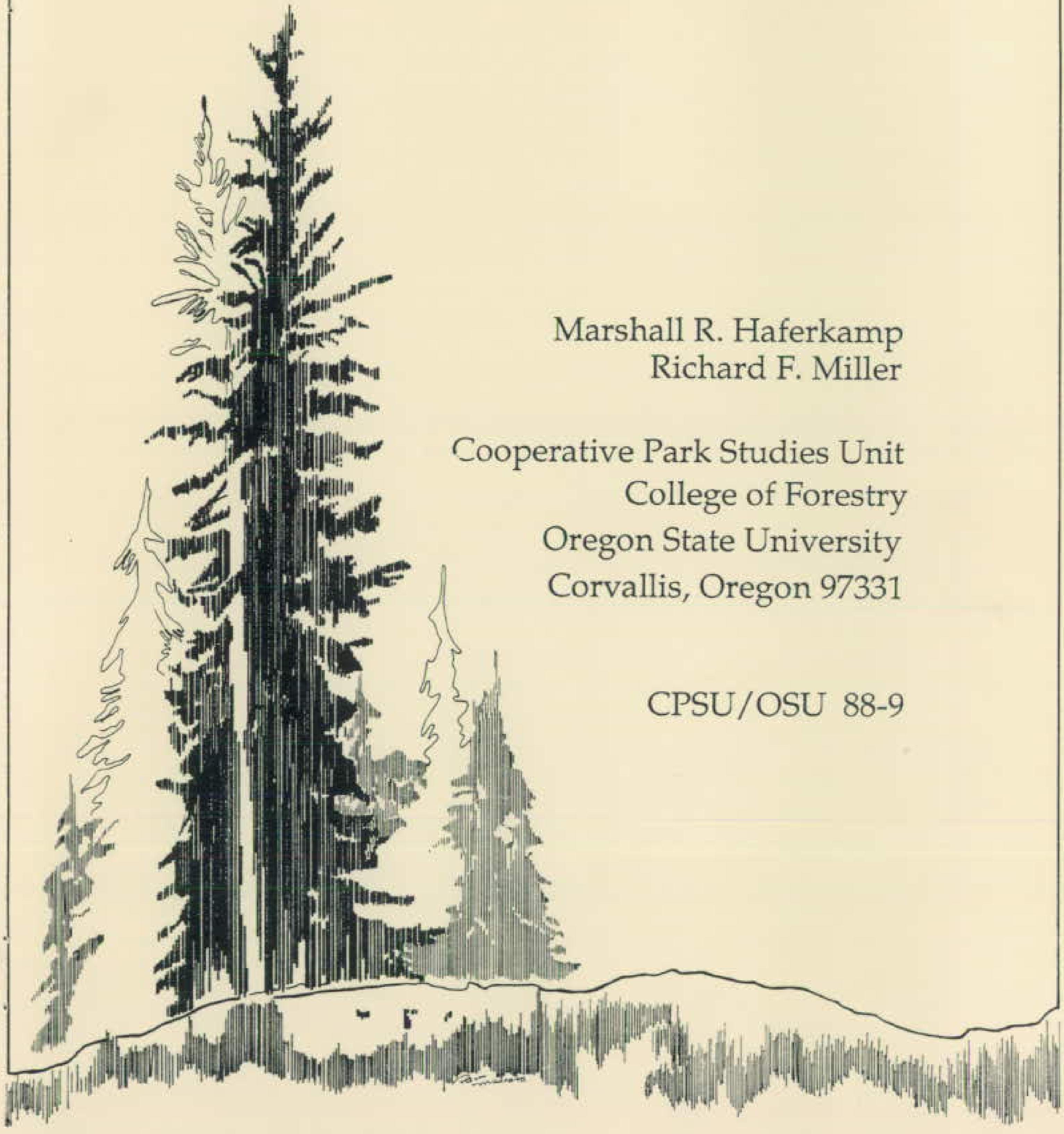
Revegetation With Native Plant Species on the John Day Fossil Beds National Monument



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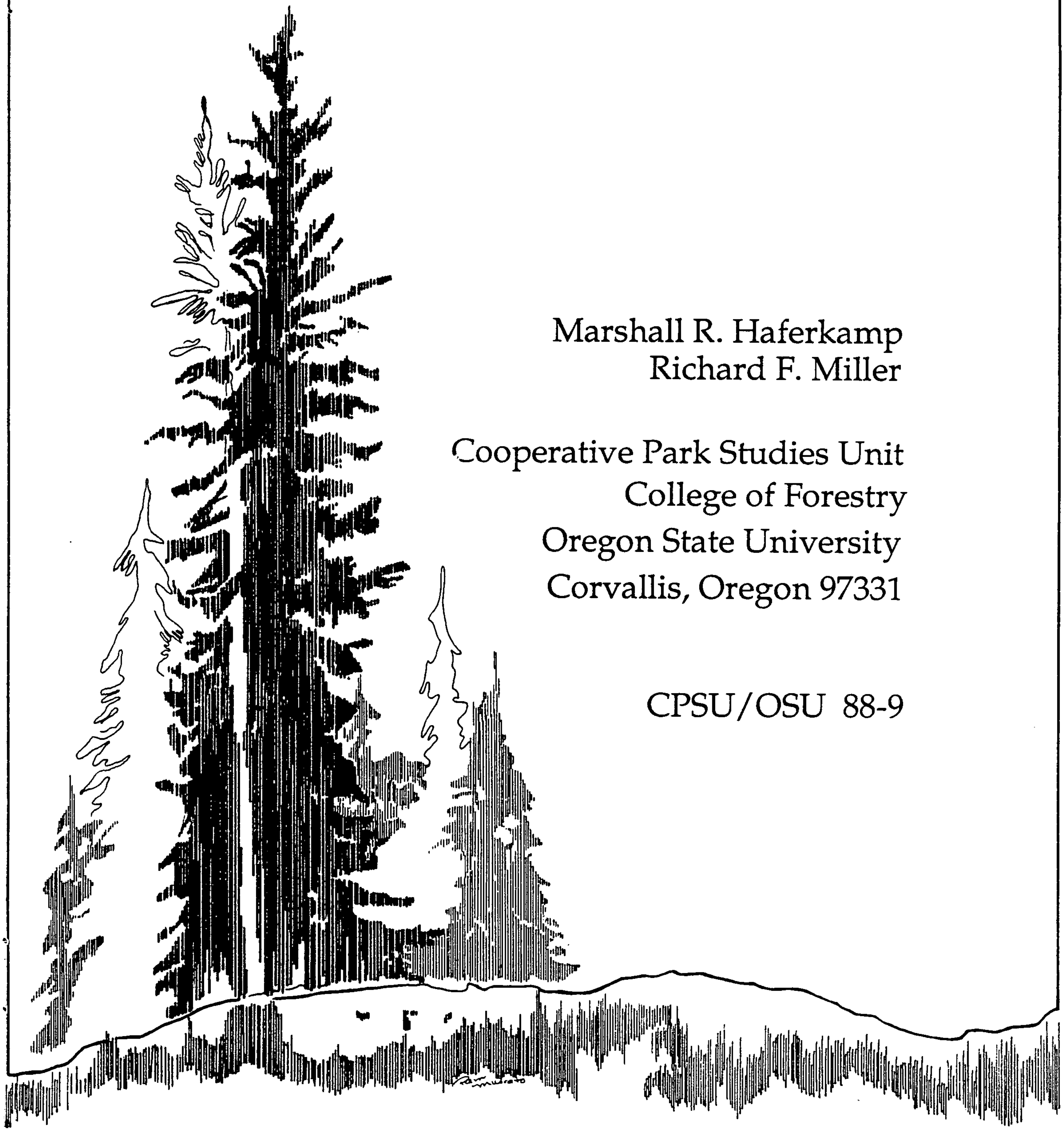

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FINAL REPORT

REVEGETATION WITH NATIVE PLANT SPECIES ON THE JOHN DAY FOSSIL BEDS NATIONAL MONUMENT

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SUMMARY

Several revegetation studies were conducted on the John Day Fossil Beds National Monument, located north of Dayville, Oregon. In these studies, we utilized conventional seedbed preparation techniques of discing, burning and herbicides. Native grass species, bluebunch wheatgrass (Secar and T2950) and basin wildrye (Magnar), were planted with a rangeland drill or broadcast before rolling plots with a land imprinter. Some seedings failed, while others were quite successful, with seedling densities exceeding 10 seedlings/m^2. Causes for some of the failures are not clear, but a major potential cause is the interaction of poor seedling vigor with environmental stress (i.e. dry soil). The results of the studies show bluebunch wheatgrass can be established with the methods used, but we have yet to establish a successful stand of basin wildrye. Reseeding rangelands has a high risk, and even though projects are designed and conducted utilizing the best available methods of seedbed preparation and planting, failures can occur when the environmental stress is too great. The potential for success can be enhanced by paying particular attention to site selection, selecting adapted species with good seedling vigor, preparing a firm weed-free seedbed, and planting at the proper season with the proper equipment.

OBJECTIVES:

(1) Evaluate mechanical, chemical and burning techniques for controlling competing vegetation and establishing seeded species, (2) evaluate the effectiveness of planting with a rangeland drill, land imprinter and hydraulic seeder-mulcher, and (3) evaluate adaptation of additional ecotypes of selected plant species for revegetating poorly vegetated slopes and valley bottoms.

JUSTIFICATION:

A large portion of the John Day Fossil Beds National Monument (JDFBNM) is in low ecological condition (Youtie and Winward 1977). Most of the area's steep and rocky topography present difficulties for using mechanical methods of seedbed preparation and planting. Seedbed preparation on these areas is limited to use of burning or chemicals, and seeding is limited to broadcasting with mulching to enhance moisture conservation.

The more gently sloping lands can be prepared and planted by conventional techniques. However, due to the presence of competing vegetation, such as cheatgrass (*Bromus tectorum* L.), quackgrass [*Agropyron repens* (L.) Beauv.] and other species, some method of seedbed preparation is required to reduce competition to a manageable level. Seeds can be planted by drilling, but the rows resulting from drilling are not the most aesthetically appealing for visitors to the JDFBNM. Thus, another technique, the land imprinter, that plants seeds in a more broken pattern was evaluated in conjunction with the rangeland drill on seedbeds prepared by conventional methods utilizing discing, burning, and chemicals.

Two species of grasses, (*Agropyron spicatum*)[1] 'Secar' and 'T 2950' and (*Elymus cinereus* Scribn. & Merr.) 'Magnar' were used in the studies. The species are native grasses that fit into the proposed management scheme for the JDFBNM, one in which they would prefer to utilize native or indigenous plant species for all improvement. Past research at this location has shown Secar can be established by broadcast seeding on the lower slopes when competition was reduced by herbicide, and mulch was used to increase the effectiveness of the soil moisture. Establishment of Secar and Magnar, however, has been poor on a bottomland site where cheatgrass and quackgrass were not adequately controlled.

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[1]*Pseudoroegneria spicata* (Pursh) A. Love has been proposed to replace the name *Agropyron spicatum* (Pursh) Scribn. and Smith (Barkworth et al. 1983).

Secar bluebunch wheatgrass, was released by the USDA, Soil Conservation Service Plant Materials Center at Pullman, Washington, in 1980. Upon release it was described as a bluebunch wheatgrass selection originating from a native plant collection made in 1938 near Lewiston, Idaho, at an elevation of 305 to 366 m. The variety was selected for its superiority in drought tolerance, forage production in precipitation zones of less than 35 cm annually, spring recovery, the ability to establish and provide ground cover, root and crown production, dryland seed yield potential, and irrigated seed yield potential (USDA Soil Conservation Service 1980). More recently, Carlson and Dewey (1987) found Secar is actually a subspecies of thickspike wheatgrass (*Elymus lanceolatus* spp. *wawawai*) and renamed it Snake River wheatgrass. This subspecies mimics bluebunch wheatgrass (*Pseudoroegneria spicata*) in the hotter, more arid parts of its range. They suggest that although the new subspecies is similar in performance and adaptation to bluebunch wheatgrass, it contains the S and H genome, and therefore, belongs to the genus *Elymus*. They also indicate Snake River wheatgrass is adapted to most bluebunch sites, is generally more productive, easier to establish, and has high potential for improvement.

T 2950 is an experimental accession of bluebunch wheatgrass that is currently being evaluated by the USDA Soil Conservation Service Plant Materials Center in Aberdeen, Idaho. The original collection was made in 1934 in the Umatilla National Forest in Asotin County, Washington, at an elevation of 968 to 1462 m. The Soil Conservation Service plans to release this variety in 1989, based on its superior forage production in the Intermountain area, potential stand establishment and seed production with irrigation.

Magnar basin wildrye is a hardy, long-lived perennial bunchgrass. The variety grows in areas with an average annual precipitation of 20 to 41 cm. It grows well in run-in areas, along gullies or water courses or on sites with the water table near the surface in lower precipitation regions. Magnar is adapted to a wide variety of soils except coarse-textured deep sands and shallow soils. Salt and alkali tolerance is good, and it withstands a relatively high water table. The variety will not, however, tolerate extended periods of inundation.

LITERATURE REVIEW:

Successful establishment of range seedings requires use of adapted species or varieties of plants, preparation of a firm, weed-free seedbed and planting seeds at the proper rate, date and depth (Plummer et al. 1955). At the JDFBNM, one must contend with a lack of precipitation (30 cm annually) especially during the summer months; temperature extremes of -17.8 to 40.6°C; and competition from cheatgrass and Sandbergs bluegrass (*Poa sandbergii* Vasey).

Plantings of perennial forage species on cheatgrass ranges have often resulted in failures, mainly because of competition between seedlings and cheatgrass plants during the first growing season (Klomp and Hull 1972). They reported seeded stands in southern Idaho were successful when cheatgrass stands were reduced to 120 plants/m^2 during the first growing season. Hull and Stewart (1948) suggested establishment of reseeded species occurred if cheatgrass densities were reduced from 3,000 to 10,000 plants/m^2 to 1,000 or fewer/m^2 by deep-furrow lister drilling, 800 or fewer/m^2 burning, or 500 or fewer/m^2 by other methods.

Cheatgrass, a winter annual, is well adapted to ranges in eastern Oregon. Seed germination occurs very rapidly after late summer or early fall rains (Hull and Stewart 1948). Young plants remain dormant during winter and renew growth early the following spring. If inadequate rainfall occurs in late summer and early fall, cheatgrass seeds do not germinate until the following spring. Fall rains in Nevada permit emergence of cheatgrass in only 1 out of 5 years (Evans and Young 1984). Roots of cheatgrass seedlings elongate more rapidly during winter than roots of bluebunch wheatgrass seedlings (Harris and Goebel 1976). The competitive advantage of cheatgrass appears to result from the ability to deplete soil moisture at deeper levels in advance of developing roots of bluebunch wheatgrass seedlings. During years of above average precipitation when soil moisture is plentiful, annuals are relatively poor competitors (Harris 1967; Harris and Goebel 1976).

Evans and Young (1984) suggest technology for cheatgrass control has three distinct bases: 1) to directly kill emerging plants; 2) to reduce the reproductive potential of the species; and 3) to put seedbed characteristics outside the range of adaptation for seed germination and seedling growth of this weedy species. Successful control of cheatgrass generally requires destruction of two successive seed crops (National Research Council 1968). They also suggest fall control of cheatgrass and seeding should be conducted only in years in which there is early and almost complete fall germination of cheatgrass. Hulbert (1955) reported all or nearly all seeds of cheatgrass germinate the first season when external conditions are favorable. Young et al. (1972), however, suggested a residue of seeds was left in the soil and litter.

Several methods suggested for seed and plant destruction include tillage, tillage plus herbicide application, and controlled burning followed by tillage or herbicides (National Research Council 1968). Burning is a desirable initial treatment for destroying seeds and removing litter of medusahead [Taeniatherum asperum (Simonkai) Nevski] infested ranges in southern Idaho (Torell and Erickson 1967). Tillage and herbicides can be used to destroy seedlings following germination of the remaining viable seeds. Removal of litter and standing dead can improve tillage as well as improve the performance of herbicides by allowing herbicides to reach target plants rather than adhering to the dense layer of dead plant material.

Several opinions have been reported in the literature about the effectiveness of fire as a tool for reducing cheatgrass stands (Klemmedson and Smith 1964). After reviewing many studies these authors suggested time of burning was very important in determining subsequent stand density. Burning in early summer at or near maturity, when seeds have not shattered, has produced light remnant stands. Young et al. (1976) reported 83 to 99% of germinable cheatgrass seed may be destroyed, depending upon the intensity of a burn. Some studies, however, have shown cheatgrass stands have increased after burns. Early summer burns can kill perennial grasses and allow cheatgrass to increase (Wright et al. 1979). Robocker et al. (1965) reported burning substantially reduced the amount of cheatgrass on ranges the next year. Burning, however, was not effective in increasing the stands of planted wheatgrasses. Planned burning in early summer when fire danger was low in southern Idaho has the potential to kill 79 to 95% of the cheatgrass and produce fair to excellent stands of grass at low cost (Hull and Stewart 1948).

Hull and Stewart (1948) reviewed several mechanical methods of seedbed preparation to control cheatgrass. Moldboard plowing was effective but costly. Heavy discing was cheaper and can be used both in the spring before seed maturity or after seed germination in the fall. Deep furrow lister drilling, where seeds are placed in the bottom of wide, deep furrows free of competition, killed 50 to 85% of the cheatgrass and provided fair to excellent stands of grass at medium cost. Deep furrows need to be formed after fall germination of cheatgrass, and seedings may fail if seed is covered with too much soil.

When chemicals are used for seedbed preparation, seeds are usually planted shortly after spraying or after a fallow treatment. Chemically prepared seedbeds, like those prepared by burning are firm, but often have a heavier cover of mulch and litter on ranges supporting annual grasses. Research data suggest several herbicides may be effective for controlling cheatgrass and seedbed preparation on rangelands. Glyphosate (N-(phosphonomethyl) glycine), a non-selective herbicide, was used in these studies. Prior results, although variable, have shown good cheatgrass control has been obtained with rates of 0.48 to 2.52 kg/ha applied when plants were in the three-leaf stage of growth (Brenchly 1981a; Brenchly 1981b; Rydrych 1981; Schirman and Thill 1979a; Schirman and Thill 1979b).

Seedings in the northern Great Basin are often planted in the late fall or very early spring (Vallentine 1980). Usually weather is favorable for a longer period in the fall than in the spring. In addition, delaying tillage operations until spring often reduces the amount of soil moisture that is available to germinating seeds and developing seedlings.

Drilling has conventionally been used to seed rangelands in the western United States. Planting with a drill provides uniform distribution of seed and proper depth of planting on firm seedbeds. On loose soils packing is usually required to achieve the degree of soil firmness needed for optimum control of planting depth, improved water holding capacity of the surface soil, enhanced capillary transfer of water to the seed, and optimum seed to soil contact (Hyder et al. 1955; Hyder and Sneva 1956; McGinnies 1962; Hyder and Bement 1969; Hyder and Bement 1970).

Broadcasting is employed where topography is too rough for drills to be used or where vast areas must be seeded, such as following large fires. Broadcast seeds are exposed to rapidly fluctuating moisture and temperature extremes and depredation by birds and rodents. Thus seed should be covered with soil when possible (Nelson et al. 1970; Goebel 1978). Chaining and other methods have been used to cover broadcast seeds (Vallentine 1980; Luke and Monsen 1984).

The land imprinter (Dixon and Simanton 1980, Anderson 1981) and the imprinting revegetation system (Dixon 1982) appear to be effective for covering broadcast seed and for creating microdepressions to reduce runoff. Results from imprinting have been variable in the southwestern United States, where much of the precipitation occurs as intense summer rains (Dixon 1980; Tye 1980; Dixon 1983; Dale 1985; Cox et al. 1986). In that environment, retention of water is critical to provide adequate moisture for seed germination and seedling establishment. Seedling emergence was improved by imprinting compared to drilling on burned seedbeds in Utah (Clary and Johnson 1983), and on mowed-disced seedbeds in southeastern Oregon (Haferkamp et al. 1987b) and by imprinting compared to chaining after aerially broadcasting seed on a burned seedbed in southern Oregon (Ganskopp 1985; Haferkamp et al. 1987a).

METHODS AND RESULTS:

Three areas within the John Day Fossil Beds National Monument were selected for study in May 1984. Two study sites, upper Foree and Sheeprock, were deteriorated *Artemisia tridentata*-*Agropyron spicatum* communities, and one, lower Foree, is a *Sarcobatus vermiculatus*-*Bromus tectorum* community. Soil at the upper Foree site is a Hack extremely stony loam, and the soil at Sheeprock is a

Simas clay loam (Dyksterhuis 1981). Soil at the lower Foree site is a Hack loam. The upper Foree and Sheeprock sites were infested with cheatgrass, and the lower Foree site contained a dense stand of quackgrass.

Seedbeds were prepared by conventional methods utilizing tillage, burning or herbicides. Secar, T2950 and Magnar were utilized in the studies. Seeds were planted by drilling with a rangeland drill or by broadcasting seed before imprinting.

Responses to methods of seedbed preparation and planting techniques were monitored by determining density and frequency of seeded species during the first two growing seasons after planting, and density, frequency, and yield during the following years. Density, canopy cover, and yields of competing species were also determined. Sampling was usually done by placing ten 30 by 60-cm quadrats diagonally across each main plot. They were placed to include at least 60 cm of drill row or 60 cm of imprint depression at each placement. In some instances only five frames were used, and where competing species were extremely dense a 30 by 30-cm frame was used. Yields were determined by clipping standing forage within the frame to ground level. All clipped forage was dried for at least 24 hours at 60°C and then weighed.

During the study temperature and precipitation were monitored at the weather station located on the Monument, and soil samples were collected for moisture determinations at selected periods. Soil samples were dried for at least 48 hours at 105°C. Moisture release curves were determined by the Oregon State University Soils Laboratory for the Sheeprock and upper Foree soils.

Sheeprock

A 1-year study was initiated at the Sheeprock site in 1984. Seedbeds were prepared by discing on May 16, June 11, and October 14. Initial discing killed living plants, and rediscing was used to destroy seedlings emerging after fall rains. On October 25, 1984, Secar was planted at rates of 200 and 300 pure live seeds (PLS)/m^2 on the disced seedbed. Seeds were either broadcast at 200 or 300 PLS/m^2 prior to rolling plots with a land imprinter filled with water (total weight 4313 kg) or planted at 200 PLS/m^2 with a rangeland drill equipped with regular furrow openers and depth bands. Planting methods were replicated four times and arranged in a randomized, complete-block design.

Table 1. Precipitation recorded at the Cant Ranch during the study period of 1984-1987.

Month	Year 1984	1985	1986	1987
	-----	-----	cm -----	-----
January		0.8	2.0	2.4
February		1.8	5.4	1.9
March		1.2	1.5	3.6
April		1.0	2.4	2.0
May		6.8	3.0	3.4
June		0.6	0.7	1.9
July		0.9	0.9	5.3
August		1.2	0.3	0.7
September		1.1	2.3	0.0
October	3.8	1.1	0.9	0.0
November	4.4	4.6	3.5	1.5
December	1.4	0.9	0.5	2.5
Total		22.0	23.4	25.2

Precipitation totaled 12.2 cm during the fall and winter (Table 1). Soil moisture averaged 21.3% on February 26 and 13.2% in the surface and 20% down to 30 cm on March 20, 1985 (Table 2). On February 26, we observed a few Secar seedlings on the site. Densities ranged from 0 to 10 seedling/m² and frequencies from 0-30% (Table 3). By late April 1985, densities of competing grasses averaged 12 and 18/m² with drilling and imprinting, respectively, while forb density averaged 46 and 75/m² with the same treatments (Table 4). Major grass species were little barley (*Hordeum pusillum* Nutt.) and cheatgrass, and major forbs were bur buttercup (*Ranunculus testiculatus* Crantz) and alfileria [*Erodium cicutarium* (L.) L'Her.]. Due to the sparse stands of Secar seedlings and dense stands of competing species, we decided to disc these plots and replant in fall 1985.

The site was disced on April 30 and June 4, 1985. Treatments were changed in 1985 to planting by broadcasting prior to imprinting. Due to the poor results from the preceding study we decided to try even higher seeding rates. Thus Secar was planted November 1985, at 215, 430, and 645 PLS/m² and T2950, supplied by the Soil Conservation Service, Aberdeen Plant Materials Center, was planted at 215 PLS/m². Treatments were replicated four times and arranged in a randomized, complete-block design.

Precipitation totaled about 12.8 cm from November through February with an additional 6.9 cm falling during March through May 1986 (Table 1). Soil moisture decreased from 27.2% in February to 10.0% in June, and continued to decrease to 9.5% in July (Table 2). In March 1986, Secar seedlings were emerging, and the stand appeared to be good. Density counts were delayed until April to allow for positive identification of seedlings. On April 8, 1986, seedlings were

Table 2. Moisture content of soil collected at selected times at the Sheeprock site.

		Planting Method	
Date	Depth (cm)	Imprint	Drill
		%	
2/26/85	0-5	19.7	22.4
	5-30	21.7	21.4
3/20/85	0-5	13.8	12.6
	5-30	21.0	19.1
1/13/86	0-5	24.5	-
	5-30	24.0	-
2/19/86	0-5	28.9	-
	5-30	25.5	-
3/28/86	0-5	14.5	-
	5-30	17.9	-
5/5/86	0-5	14.2	-
	5-30	13.7	-
6/5/86	0-30	11.1	-
6/16/86	0-30	10.0	-
7/16/86	0-30	9.5	-
3/11/87	0-5	22.4	-
	5-30	19.8	-
4/13/87	0-5	13.0	-
	5-30	12.9	-

Table 3. Density and frequency of Secar bluebunch wheatgrass seedlings emerged in 1985 on the Sheeprock site at the John Day Fossil Beds National Monument. Seedbeds were prepared and plots planted in 1984.

Planting Method		
Drill	1 X Imprint	1.5 X Imprint
	number/m^2	
0.4	0.8	0.6
	%	
8	10	10

in the 2 to 5-leaf stage of development. Seedling densities were 33, 55, 99, and 51/m^2 for the 215, 430, and 645 PLS Secar and the 215 PLS T2950 rates, respectively (Table 5). The densities were well above the 10 seedlings/m^2 generally required for an excellent stand rating. Frequency averaged over 90% for all treatments (Table 5).

Density of competing species totaled 115 seedlings/m^2 and was composed mainly of bur buttercup, wallflower mustard (Erysimum repandum L.), jim hill mustard (Sisymbrium altissimum L.), and blue mustard [Chorispora tenella (Pall.) DC] (Table 6). Weed canopy cover was 69% on May 5 and increased to 86% by June 16, when weed dry weight was 5170 kg/ha. By June most of the weedy species were drying while the bluebunch wheatgrass plants were flowering.

During September 1986 through February 1987, 11.5 cm of precipitation fell on the site with an additional 3.6 cm occurring in March (Table 1). Soil moisture in the 0 to 30-cm depth averaged 21% in early March and 13% in mid April (Table 2). On March 11, 1987, plant densities averaged 20, 30, 47, and 17 plants/m^2 for the 215, 430, and 645 PLS Secar and 215 PLS T2950 rates, respectively (Table 7). Frequency averaged 96% over all treatments (Table 7). On June 2, 1987, bluebunch densities were 17, 25, 39, and 10 plants/m^2, frequency averaged 82, 100, 98, and 65%, and dry weight averaged 79, 106, 209, and 73 kg/ha for the 215, 430, and 645 PLS Secar and 215 PLS T2950 rates, respectively (Table 7). Weed canopy cover averaged 76%, while dry weight of weeds averaged 1232 kg/ha. The values indicate establishment was excellent for all treatments.

Table 4. Density of competing grass and forb plants growing on April 30, 1985 on the Sheeprock site at the John Day Fossil Beds National Monument. Seedbeds were prepared by discing in 1984.

Plants	Planting Method	
	Drill	Imprint
	- - - - - number/m^2 - - - - -	
Grass	11	18
Forbs	46	75
Total	58	93

Abandoned Field-Foree

The Sheeprock study was repeated at a site located at lower Foree. The abandoned field contained scattered plants of tall fescue (*Festuca arundinacea* Schreb.) and alfalfa (*Medicago sativa* L.), patches of quackgrass, and was infested with cheatgrass. The site was burned on September 24, 1985. Patches of quackgrass which greened up after burning were sprayed on April 8, 1986, with glyphosate from a hand operated backpack sprayer. On June 6, 1986, the area was disced to kill annual forbs and grasses before they produced seed. The site was planted on October 14, 1986, to Secar and T2950 bluebunch wheatgrass. The four replications were arranged in a randomized, complete-block design.

Precipitation totaled 4.9 cm during October to December (Table 1). Soil moisture increased from 5.9% in mid October to 6.5% in late December in the 0 to 5-cm depth (Table 8). No seedlings had emerged by December 22, 1986. As of March 11, 1987, only a few bluebunch seedlings had emerged, however, a number of weed seedlings were present. On April 23, 1987, bluebunch densities were 32, 46, 51 and 29 seedlings/m² for the 215, 430, and 645 PLS Secar and 215 PLS T2950 rates, respectively (Table 9). Frequency averaged 80% for all treatments (Table 9).

Densities were lower than at Sheeprock in April 1986 except for the 215 PLS Secar rate. However, seedling densities were higher than the 10/m² needed for an excellent stand. Density of weed competition was 27 plants/m² on April 23 when canopy cover was 58% (Table 10). By June 2, weed canopy cover had increased to 81%, and dry weight averaged 2912 kg/ha (Table 10). The weed species were similar to Sheeprock in 1986. By fall 1986, the seedlings were still small and some had been grazed by rabbits or deer. Another year will be required to determine the success of this seeding.

Table 5. Density and frequency of Secar and T-2950 bluebunch wheatgrass seedlings growing on April 8, 1986 on the Sheeprock site at the John Day Fossil Beds National Monument. Seedbeds were prepared by discing in 1985 and plots were planted in fall 1985.

	Seeding Rate (PLS/m²)		
Accession	215	430	645
	- - - - - - seedlings/m² - - - - -		
Secar	33	55	99
T-2950	51	-	-
	- - - - - - - - - - % - - - - - - - -		
Secar	90	98	98
T-2950	100	-	-

Table 6. Density, canopy cover and yield of competing species growing in 1986 and 1987 on the Sheeprock site at the John Day Fossil Beds National Monument. Seedbeds were prepared by discing in 1985 and plots were planted in fall 1985.

Date	Competing Plants		
	Grass	Forb	Total
	number/m^2		
4/24/86	5	110	115
	%		
5/5/86	-	-	69
	%		
6/16/86	-	-	86
	kg/ha		
	-	-	5170
	%		
6/2/87	-	-	76
	kg/ha		
	-	-	1232

Upper Foree

Drilling and Imprinting. A 3-year study was initiated at the upper Foree site in 1984. Seedbeds were prepared either by discing in mid-May and mid-October, 1984, or burning in mid-June 1984, followed by discing or spraying with glyphosate at 1.1 kg/ha active ingredient in mid-October 1984. The initial discing killed plants of existing vegetation, and burning removed the standing crop. Subsequent discing and spraying were used to control seedlings emerging from fall germinating seeds on disc or burned plots. On October 31, 1984, Secar was planted at 200 PLS/m^2 by broadcasting prior to land imprinting or with a rangeland drill equipped with regular openers and depth bands. Treatments were arranged in a split-block design with four replications.

Table 7. Density, frequency and yield of Secar and T-2950 bluebunch wheatgrass plants growing in 1987 on the Sheeprock site at the John Day Fossil Beds National Monument.

Date	Accession	Seeding Rate (PLS/m^2) 215	430	645
		number/m^2		
3/11/87	Secar	20	30	47
	T-2950	17	-	-
		%		
	Secar	95	95	100
	T-2950	93	-	-
		number/m^2		
6/2/87	Secar	17	25	39
	T-2950	10	-	-
		%		
	Secar	82	100	98
	T-2950	65	-	-
		kg/ha		
	Secar	79	106	209
	T-2950	73	-	-

Precipitation from planting to late April totaled 14.4 cm (Table 1). Soil moisture in the 0 to 5-cm depth decreased from 15.6% in late February to 8.8% in late April (Table 11). Soil moisture in the 5 to 30-cm depth decreased from 20.2% in February to 15.3% in April. Secar seedling densities ranged from 0 to 2.6/m^2 on April 25, 1985 (Table 12). Seedlings were particularly sparse in replication 1, located highest on the slope, nearest the rest area road. Seedling densities averaged 1.4 seedlings/m^2 whether planted by drilling or imprinting on the disced and burned-disced seedbeds (Table 12). However, seedling establishment was markedly better with drilling (2.6/m^2) than with imprinting (0/m^2) on the firm burned-sprayed seedbeds. Frequency ranged from 0 to 28% (Table 12). Average competing grass densities ranged from 8 to 24/m^2, and average forb densities ranged from 45 to 96/m^2 (Table 13).

Table 8. Moisture content of the soil collected at selected times of the abandoned field site at Foree.

Date	Depth (cm)	Position on Imprint		
		Top	Side	Bottom
		- - - - - - - - % - - - - - - - -		
10/14/86	0-5	-	-	5.9
12/22/86	0-5	15.7	-	16.5
2/17/87	0-5	20.5	20.5	22.7
	5-30	-	-	20.3
4/13/87	0-5	5.1	6.4	9.1
	5-30	-	-	11.3

By June 7, 1985, Secar seedling densities averaged 2 and 3 seedling/m² with imprinting and drilling on seedbeds disced in October (Table 12). Significantly more seedlings (2.4/m²) were established by drilling vs. imprinting (0.3/m²) on the firm, burned-sprayed seedbeds. Frequency ranged from 10 to 30% (Table 12). None of the stands achieved the 10 seedling/m², needed for a successful seeding. Canopy cover of competing species averaged 17 to 18% on the disced and burned-disced seedbeds and 8% on the burned-sprayed seedbeds (Table 13). Dry matter yields of competing species averaged 442 and 500 kg/ha on the disced and burned-disced seedbeds, but only 90 kg/ha on the burned-sprayed seedbeds (Table 13). Competition was significantly reduced by the burn-spray treatment, but the firm seedbed was not optimum for seeding with the land imprinter filled with water.

The reason for the relatively poor establishment of Secar in lieu of the successful control of competing vegetation was not readily apparent. We have, however, observed sparse stands of Secar such as these at other locations. The seed source used in this study and others near Burns, Oregon, contained a relatively large percentage of small seeds. We were concerned these small seeds might not germinate and seedlings might not establish as readily from them as from large seeds. Thus, the effect of the difference in seed size on seed germination and seedling development was investigated in another study.

Table 9. Density and frequency of Secar and T-2950 bluebunch wheatgrass seedlings emerged by April 23, 1987 on the abandoned field located at Foree on the John Day Fossil Beds National Monument. Seedbeds were prepared in 1985 and 1986 and plots were planted in fall 1986.

Accession	Seeding Rate (PLS/m^2) 215	430	645
	number/m^2		
Secar	32	46	51
T-2950	29	-	-
	%		
Secar	78	82	80
T-2950	80	-	-

Table 10. Density, canopy cover and yield of competing species growing in 1987 on the abandoned field located at Foree on the John Day Fossil Beds National Monument. Seedbeds were prepared in 1985 and 1986 and plots were planted in fall 1986.

	Sample Date 4/23	6/2
Density (number/m^2)	27	-
Canopy Cover (%)	58	81
Yield (kg/ha)	-	2912

By June 1986, plant densities of Secar ranged from 0.3 to 2.0/m^2 with frequencies of 5 to 20% (Table 14). Secar yields ranged from 1 to 51 kg/ha while yields of competing species ranged from 678 to 1055 kg/ha (Table 15). The higher yields occurring on replications with deeper soils, located lower on the slope, was still evident in 1986. Average yields were 0, 20, 24 and 50 kg/ha for blocks 1, 2, 3 and 4, respectively. Except on a few plots, none of the densities or yields of Secar were considered adequate or satisfactory to meet the objective of revegetating the site with perennial grasses.

Table 11. Moisture content of soil collected at selected times at the upper Foree site.

		Seedbed Preparation			
		Disc-Disc		Burn-Spray	
Date	Depth (cm)	Imprint	Drill	Imprint	Drill
		----------	%	----------	
2/26/85	0-5	16.7	13.8	16.7	15.4
	5-30	20.0	18.0	20.8	22.0
3/20/85	0-5	9.7	9.0	7.7	11.1
	5-30	15.1	15.1	20.6	19.0
4/25/85	0-5	8.5	9.9	6.8	10.0
	5-30	12.0	13.8	20.5	14.8
5/22/85	0-5	3.5	4.3	3.8	4.5
	5-30	10.3	13.0	17.2	13.9
6/13/85	0-5	5.1	5.1	7.7	7.8
	5-30	10.4	10.1	15.1	13.6
7/16/85	0-30	8.1	5.8	10.3	7.6
8/19/85	0-5	2.6	2.4	2.0	2.3
	5-30	6.2	5.9	6.6	8.5
9/24/85	0-5	3.0	3.1	3.0	3.2
	5-30	6.2	7.3	8.2	8.4
1/13/86	-	Soil was frozen			
2/19/86	0-5	23.0	22.0	23.6	24.7
	5-30	25.4	21.8	23.3	24.0

<u>Drilling</u>. Beginning on June 4, 1985, another study was initiated at upper Foree. Seedbeds were prepared by burning on June 4, 1985, or burning in June 1985 followed by spraying with 1.1 kg/ha active ingredient glyphosate on March 26, 1986. Secar bluebunch wheatgrass was planted on March 28 and October 15, 1986, at 150 PLS/m² with a rangeland drill equipped with regular openers and depth bands. One-half of each 9 x 12-m plot was mulched with straw immediately following planting at 440 kg/ha. Treatments were arranged in a split-block design with seedbed preparation as major plots, season of planting as subplots, and mulching as sub-subplots. Treatments were replicated four times.

Table 12. Density and frequency of Secar bluebunch wheatgrass seedlings in 1985 on the upper Foree site.

		Planting Method	
Date	Seedbed	Drill	Imprint
		---- number/m^2 ----	
4/25/85	Burn-Spray	2.6	0
	Burn-Disc	1.3	1.5
	Disc-Disc	1.6	1.3
		------ % ------	
	Burn-Spray	28	0
	Burn-Disc	20	20
	Disc-Disc	28	15
		---- number/m^2 ----	
6/7/85	Burn-Spray	2.4	0.3
	Burn-Disc	3.0	2.4
	Disc-Disc	3.0	1.6
		------ % ------	
	Burn-Spray	30	10
	Burn-Disc	22	35
	Disc-Disc	22	10

In the spring planting, seedlings did not emerge until after May 21 when 5.4 cm rain was received (Table 1). Soil moisture in the 0 to 5-cm depth averaged 13.2% at planting, and 9.3 and 7.2% on the sprayed and unsprayed seedbeds, respectively, on May 5, 1986 (Table 16). By June 6, 1986, soil moisture in the 0 to 30-cm depth averaged 14.1% on sprayed seedbeds and 10.1% on unsprayed seedbeds. On June 6, seedling densities were 8.1 and 4.0/m^2 on the mulched and non-mulched burned-sprayed plots and less than 1/m^2 on the burned plots (Table 17). Only the mulched, burned-sprayed treatment produced a successful seeding by June; however, the seedlings were small.

Table 13. Density, canopy cover and standing crops of competing species growing on the seeded plots at upper Foree in 1985.

Date	Seedbed	Planting method: Drill	Imprint
		Grass density (number/m²)	
4/30/85	Burn-Spray	8	17
	Burn-Disc	18	20
	Disc-Disc	13	24
		Forb density (number/m²)	
	Burn-Spray	96	72
	Burn-Disc	65	50
	Disc-Disc	46	45
		% canopy cover	
6/7/85	Burn-Spray	9	8
	Burn-Disc	16	18
	Disc-Disc	21	15
		Total yield (kg/ha)	
	Burn-Spray	71	109
	Burn-Disc	459	541
	Disc-Disc	378	506

During June and July, soil moisture decreased to 9.2% in the 0 to 30-cm depth even though 1.6 cm of rainfall was received. The rainfall occurred as showers of less than 0.5 cm. Burning and spraying significantly reduced weed competition. Weed canopy cover was 9 and 29%, and weed dry weight was 69 and 396 kg/ha for the burned-sprayed and burned treatments, respectively (Table 18). By June 1987, plant densities in the spring planted plots were significantly greater on the burned-sprayed (2.2/m²) than on the burned seedbeds (0/m²) (Table 19). Frequency was 24%, and dry weight was 25 kg/ha in the spring planted burned-sprayed plots (Table 19).

Seedlings began to emerge from the October 15 planting by December 22, 1986, following 4.9 cm of precipitation during October to December 1986. An additional 4.3 cm occurred during January through April (Table 1). Soil moisture increased to 17 to 21% in the 0 to 30-cm depth in February (Table 16). By April 13, soil moisture decreased to an average of 4 and 11.6% in the 0 to 5-cm and 5 to 30-cm depth, respectively. On April 23, 1987, Secar densities averaged 35 seedlings/m², and frequency averaged 92% in the fall planting (Table 19). Plant densities were similar among seedbed treatments. The fall seeding was more successful than the spring seeding based on plant density and frequency of distribution. Weed canopy cover and dry weight were still reduced on the burned-sprayed in 1987. Weed canopy cover was 47 and 60%, and dry weight was 220 and 334 kg/ha on the burned-sprayed and burned seedbeds, respectively (Table 20).

Table 14. Plant density frequency and yield of Secar bluebunch wheatgrass determined on June 16, 1986, on plots planted in fall 1985 on the upper Foree site at the John Day Fossil Beds National Monument.

	Planting Method	
Seedbed	Drill	Imprint
	- - - number/m² - - - -	
Burn-Spray	2.0	1.5
Burn-Disc	1.9	0.3
Disc-Disc	1.3	0.7
	- - - - - - % - - - - -	
Burn-Spray	18	20
Burn-Disc	18	5
Disc-Disc	20	10
	- - - - - -kg/ha - - - -	
Burn-Spray	26	39
Burn-Disc	17	1
Disc-Disc	51	5

Table 15. Canopy cover and yield of competing species growing on June 16, 1986, on plots planted in fall 1985 on the upper Foree site at the John Day Fossil Beds National Monument.

Seedbed		
Burn-Spray	Burn-Disc	Disc-Disc
	%	
44	60	59
	kg/ha	
678	1055	826

Table 16. Moisture content of soil collected at selected times on the upper Foree site.

		Seedbed			
		Burn		Burn-Spray	
Date	Depth (cm)	0-Mulch	Mulch	0-Mulch	Mulch
		%			
3/28/86	0-5	-	-	13.2	-
	5-30	-	-	16.3	-
5/5/86	0-5	6.9	7.5	9.4	9.3
6/5/86	0-30	9.5	8.9	10.9	12.5
7/16/86	0-30	9.5	9.2	9.4	9.3
10/22/86	0-5	3.6	-	4.1	-
2/17/87	0-5	16.8	21.2	18.5	17.8
	5-30	19.0	18.4	18.4	20.0
4/13/87	0-5	3.6	4.3	3.5	4.7
	5-30	11.5	11.9	11.1	12.0

Table 17. Seedling density and frequency of Secar bluebunch wheatgrass on June 5, 1986, on the upper Foree site of the John Day Fossil Beds National Monument. Plots planted in spring 1986.

Seedbed			
Burn		Burn-Spray	
0-Mulch	Mulch	0-Mulch	Mulch
number/m²			
0.5	0.3	4.0	8.1
%			
5	3	35	58

Lower Foree

Seedbed preparation at lower Foree included burning to remove standing forage, spraying to control quackgrass, and discing to reduce annuals and to loosen the soil. The site was initially burned in October 1984. Stands of quackgrass and other vegetation were sprayed with glyphosate at 2.2 kg/ha active ingredient on June 13, 1985, and burned on September 24, 1985, to remove residue. Small areas of resprouting quackgrass were sprayed with glyphosate from a hand operated backpack sprayer on April 8, 1986. Plots were disced on June 6, 1986, to kill annual forbs and grasses before they produced seed. The area was planted on October 7 and 8, 1986, with Magnar basin wildrye. Seed was broadcast at 215, 430, and 645 PLS/m² before imprinting. Treatments were replicated four times and arranged in a split-block design, with years of planting as major plots and seeding rates as subplots.

No seedlings had emerged by December 22, 1986, when soil moisture averaged 32.7% in the bottom of the imprints (Table 21), and no seedlings were observed at any time during the 1987 growing season. Thus, these plots should be disced and planted again to Magnar basin wildrye. The exact cause of the lack of emergence is not known.

Table 18. Canopy cover and yield of competing species growing on June 16, 1986, on the upper Foree site of the John Day Fossil Beds National Monument. Seedbeds were prepared in 1985 and plots planted in spring 1986.

Seedbed	
Burn	Burn-Spray
- - - - - - % - - - - - - -	
29	9
- - - - - - kg/ha - - - - -	
396	69

Seedling Development

The seed planted in 1984 at upper Foree and Sheeprock contained a number of small seeds causing the seed lot to contain more seeds per kg than has been reported for foundation Secar. We speculated the poor performance of seedings at both locations may have resulted from an interaction of seed size and environmental conditions during the seed germination and seedling development phases. Another study was initiated at Burns, Oregon, to determine the effect of seed size on germination and seedling development in high and low light. Low light conditions are often encountered by many emerging seedlings when large amounts of competing vegetation are present.

The commercial seed lot was separated by air into a light and heavy segment. Foundation seed of Secar and seed of T2950 were obtained from the Soil Conservation Service in Pullman, Washington, and Aberdeen, Idaho, respectively. Samples of seed were counted and weighed (Table 22). Next seeds were germinated for 21 days in a controlled environment of 20°C with 12 hours light and 12 hours dark. Following the germination trial, seeds were germinated, and 6 to 7 days after imbibition began, seedlings were collected when shoots were 25 mm long and the first seminal root was 15 mm long.

Seedlings were transplanted into containers that were 20 cm long and 4 cm in diameter with an effective volume of 125 cm^3. One seedling was planted in each container filled with a sandy loam soil, and tubes were watered daily through out the study. Fifty tubes in each light regime, high (full sun light, peak photosynthetic active solar radiation of 1900$\mu\epsilon/m^2/s$) and low (50$\mu\epsilon/m^2/s$), were planted for each seed source. Tubes were randomly arranged in each light regime. The shaded plants received additional light as the sun was low on the horizon, in the morning and evening.

Table 19. Density, frequency and yield of Secar bluebunch wheatgrass seedlings and plants growing in 1987 on plots planted in spring and fall 1986 on the upper Foree site at the John Day Fossil Beds National Monument.

Planting Date	Date Measured	Seedbed: Burn 0-Mulch	Seedbed: Burn Mulch	Seedbed: Burn-Spray 0-Mulch	Seedbed: Burn-Spray Mulch
		plants/m²			
Spring 1986	6/2/87	0	0	1.7	2.7
		kg/ha			
		0	0	15	35
		% frequency			
		0	0	18	30
		seedlings/m²			
Fall 1986	4/23/87	31	24	39	47
		% frequency			
		88	82	98	100

Table 20. Canopy cover and yield of competing species growing on June 2, 1987, on the upper Foree site of the John Day Fossil Beds National Monument. Seedbeds were prepared in 1985 and plots planted in spring and fall 1986.

Seedbed	
Burn	Burn-Spray
- - - - - - - - % - - - - - - -	
60	47
- - - - - - - - -kg/ha - - - - - -	
334	220

Table 21. Moisture content of soil collected at selected times at the lower Foree site.

Date	Depth (cm)	Position on Imprint		
		Top	Side	Bottom
		- - - - - - - -%- - - - - - - - -		
10/14/86	0-5	-	-	7.7
12/22/86	0-5	28.3		32.7
2/17/87	0-5	28.9	27.1	31.2
	5-30	-	-	29.5
4/13/87	0-5	9.2	9.6	14.2
	5-30	-	-	23.7

Seedlings (up to 10 per source) were collected when a majority of each selection attained the two, three and four-leaf stages. At collection, intact root systems were separated from the soil column by washing with water, and plants were stored in a freezer in sealed plastic bags until measurements were taken. Measurements included number, length and dry weight of leaves, seminal roots and nodal roots.

The experiment was run twice during the periods, July 15 through August 21 and August 21 through October 22, 1985. Data were analyzed by analysis of variance to determine if difference existed between seed sources and stages of leaf development. Regression analyses were used to evaluate differences between stages of seedling development represented by differences in leaf number. Only a portion of the data will be presented in this report, but a completed draft copy of the manuscript submitted for publication will be given to the Park Service at a later date.

The data in Table 22 suggest there is a significant difference in size of seed among the four sources. The lightest being the light-commercial source and the heaviest being T2950. Results of the germination trial (Table 23) show total germination for T2950 and the heavy-commercial lot was significantly better than germination of foundation Secar and the light-commercial.

Germination based on germinable seeds during the 4, 7 and 9 days after imbibition began, was significantly different between T2950 and the other three sources (Table 24). The difference resulted from the fact T2950 germination was 32 and 87% by days 4 and 7, respectively, while the averages for the other three sources were 7.3 and 72%. This rapid germination by T2950, meant imbibition of these seeds had to begin 3 days later than for seeds of the other sources for the seedling development study.

During the seedling development study, survival of seedlings ranged from 99% for heavy-commercial Secar in low light to 80% for light-commercial in high light (Table 25). The seminal root system generally consisted of three fine highly branched roots (Table 26). As seedlings developed, seminal root length increased for all sources in Run I-sun and shade, Run II-sun and light-commercial in Run II-shade. Seminal length tended to peak at the three-leaf stage for the other seed sources in the cooler Run II-shade. Weight of the seminal root system consistently increased in weight for all sources through the four-leaf stage (Table 26).

Table 22. Weight of Secar and T2950 bluebunch wheatgrass seedlots used in the germination and seedling development study.

Source	Weight (mg/100 Seeds)
Secar	
Light	210
Heavy	286
Foundation	316
T2950	510

Table 23. Total germination of Secar and T2950 bluebunch wheatgrass.

Source	Total Germination (%)
Secar	
Light	66
Heavy	85
Foundation	74
T2950	90

Table 24. Germination of Secar and T2950 bluebunch wheatgrass seeds at 20°C. Data are based on germinable seed.

Source	Days of Imbibition 4	7	9	r^2	Regression Equation
		-%-			
Secar					
Light	6	64	86	.91	$y = -.6186 + .18x$
Heavy	6	76	93	.94	$y = -.5466 + .1606x$
Foundation	10	76	94	.94	$y = -.5376 + .1704x$
T2950	32	87	92	.82	$y = -.1290 + .1246x$

Table 25. Percent survival of Secar and T2950 bluebunch wheatgrass seedlings in high and low light.

Source	Light Regime High	Low
	-%-	
Secar		
Foundation	88	96
Heavy	91	99
Light	80	93
T2950	93	97

Nodal roots first occurred in the two-leaf stage, and by the four-leaf stage 90% of the plants had developed nodal roots. The two to four slightly-branched roots that began developing at the two-leaf stage were slightly larger than the seminal roots. Even larger unbranched roots began developing in the three- and four-leaf stage and when tillering occurred. Development of tillers occurred in the three-leaf stage in full sun light and in the four-leaf stage in the shade.

The first set of nodal roots probably are similar to the seminal lateral roots described by Hassanyar and Wilson (1978) for crested wheatgrass [Agropyron desertorum (Fisch.) Schult.] and Russian wildrye (Elymus junceus Fisch.), and the larger roots developing in the four-leaf stage are the adventitious roots described by Hyder (1974). Hyder (1974) indicated that the survival of perennial grasses appear to ultimately depend on development of these adventitious roots.

Average nodal root number increased significantly with an increase in leaf number in the sun and shade in Run I and for all sources but heavy-commercial Secar in Run II-shade. Length and weight of the nodal root system increased with an increase in leaf development in all runs except Run II-sun (Table 27). As with nodal root number, root length and weight appeared to peak at the three-leaf stage of development (Table 27). Seedlings of T2950 were slightly more advanced with actual leaf numbers of 1.8, 3.4 and 4.1, at the two, three and four leaf stages, respectively, while average leaf number of the other three sources were 1.6, 2.6 and 3.5.

The reduction in nodal root development for the Secar sources may have been a response to exposure to cold temperature. During Run II, all seedlings were exposed to colder temperatures with the minimum being below freezing for 34 days. Of those 34 days, minimum temperatures were below -6.5°C for 7 days. In contrast, the temperature was never below freezing in Run I. The more rapidly developing T2950 seedlings were collected several days earlier, thus, they were not exposed to as many cold nights. These data suggest that of the sources used, T2950 seedlings would develop more rapidly than Secar in environmental conditions similar to those utilized in the study, and in conditions similar to those encountered in Run II-sun nodal root development would be greater for T2950. The T2950 seedlings, thus, might perform better than Secar seedings, in fall seedings where seeds germinate in the fall when minimum temperatures are falling below freezing.

Table 26. Seminal root numbers, lengths, and weights for Secar and T2950 seedlings.

Run	Sun	Source	Leaf Stage 2	3	4
			number		
I	Sun	Light	3.2	2.8	3.1
		Heavy	3.8	2.8	2.7
		Foundation	3.5	3.4	3.5
		T2950	3.2	4.2	3.3
	Shade	Average	3.0	3.6	3.3
II	Sun	Average	2.8	3.2	5.3
	Shade	Light	3.2	3.0	3.1
		Heavy	2.6	3.0	3.2
		Foundation	3.0	2.3	3.0
		T2950	3.2	3.0	2.9
			length (mm)		
I	Sun	Average	178	304	508
	Shade	Average	116	301	481
II	Sun	Average	119	304	509
	Shade	Light	99	222	356
		Heavy	142	234	237
		Foundation	81	199	140
		T2950	206	706	661
			weight (mg)		
I	Sun	Average	1.1	2.1	3.6
	Shade	Average	1.1	1.6	3.3
II	Sun	Average	1.2	2.6	4.6
	Shade	Average	1.2	1.8	2.7

Table 27. Nodal root numbers, lengths, and weights for Secar and T2950 seedlings.

Run	Sun	Source	Leaf Stage 2	3	4
			- - - - - - - - number - - - - - - - -		
I	Sun	Average	0.2	1.6	3.0
	Shade	Average	0.0	0.7	2.5
II	Sun	Average	1.5	2.2	1.5
	Shade	Light	0.4	1.4	3.4
		Heavy	0.8	2.8	2.2
		Foundation	1.8	2.0	3.0
		T2950	0.4	1.8	2.5
			- - - - - - - length (mm) - - - - -		
I	Sun	Average	4	56	187
	Shade	Average	0	16	146
II	Sun	Light	7	98	68
		Heavy	11	53	68
		Foundation	18	48	17
		T2950	12	154	278
	Shade	Average	11	56	179
			- - - - - - - weight (mg) - - - - -		
I	Sun	Average	0.1	0.4	2.6
	Shade	Average	0.0	0.2	2.0
II	Sun	Light	0.1	1.5	1.2
		Heavy	0.1	0.6	0.7
		Foundation	0.3	0.6	0.2
		T2950	0.1	1.6	6.0
	Shade	Average	0.1	0.7	2.6

DISCUSSION AND MANAGEMENT IMPLICATIONS:

Preparation of a relatively weed-free seedbed is a necessity for establishing successful range seedings. This phenomena has been reported in the literature many times (Vallentine 1980), and data from the upper Foree site indicate this is true for the JDFBNM. The main thrust of the current research was to reduce competition from cheatgrass. Other species of annual forbs were present, but these did not appear to provide competition severe enough to cause seeding failures. The only highly competitive perennial species encountered in these studies was quackgrass, which was controlled with the combination of burning and spraying with glyphosate. Other areas on the Monument, infested with white top [*Cardaria draba* (L.) Hand], field bindweed (*Convolvulus arvensis* L.) and Russian knapweed (*Centaurea repens* L.), still are in need of restoration.

One should plan and utilize seedbed preparation practices that kill established target plants and remove or reduce seed reserves of competing species. This usually requires a systems approach, and very seldom can successful seedbeds be obtained with a "one-shot" approach or one method applied at one time. The "one-shot" approach may work in years with abundant precipitation, that is adequate to support the seeded species and competition, or when one is dealing with a homogeneous plant population. This, however, is usually the exception and not the rule. The conventional seedbed preparation techniques utilized in these studies can be used successfully at the JDFBNM. To enhance success one needs to consider the following important points: (1) what is the potential of the site in question, (2) what competing species are growing on the site, (3) how competitive are the species to the proposed seeded species, and (4) what techniques will kill mature plants and seedlings and (5) when should the techniques be applied to be the most successful? Many publications are available that describe currently recommended and approved methods for control of many plant species (Vallentine 1980, Romo and Krueger 1985a, Romo and Krueger 1985b, Williams et al. 1987). Some of these methods are successful most of the time, and some are successful only part of the time. Used improperly many will fail.

The land imprinter appears to be a useful implement used in combination with broadcasting seed for planting loose or coarse textured soils. With the imprinter as with other types of roller or press-wheel seeders (Beutner and Anderson 1944, Hyder et al. 1961, Hyder and Bement 1969, Hyder and Bement 1970, Marlatt and Hyder 1970, Vallentine 1980), loose soil can be firmed prior to or during planting, thus, improving seed-to-soil contact and controlling planting depth. When working on firm soils, other techniques (i.e. drilling) appear better, since full 10-cm imprints are not formed and much of the broadcast seed is left uncovered on the soil surface. The major benefits of forming full imprints are more of the seed broadcast in front of the imprinter will be pressed into the soil, improving seed-to-soil contact; deeper imprints provide emerging seedlings some protection from wind; and the rougher surface occurring with deeper imprints should enhance snow catchment and water infiltration compared to a smoother surface. The planting patterns obtained at the JDFBNM with the imprinter appear to be aesthetically more appealing than drill rows.

Establishment of both Secar and T2950 appear possible on the Monument. Failures, however, can occur even when the best techniques of seedbed preparation and planting are utilized. The plantings at Sheeprock and upper Foree during 1984 and at lower Foree in 1986 are good examples. The environmental conditions during seed germination and seedling development are critical. The environmental stresses become even more critical when planting species whose seedlings exhibit low vigor. Secar was selected for improved seedling vigor compared to other accessions, and based on data from these studies seedlings emerging from the large seeds of T2950 appear to be even more vigorous. The Soil Conservation Service indicates Magnar stands establish slowly, and recommend planting into a clean, firm, weed-free seedbed (SCS 1982). They suggest seed should be planted in late fall or early spring, and seedings made in late spring or early summer are likely to fail even with irrigation. Roundy (1985) working in Nevada found supplemental irrigation enhanced establishment of Magnar in some years, and he reported that basin wildrye seedlings were more sensitive to salt and moisture stress than were seedlings of Jose tall wheatgrass [Agropyron elongatum (Host) Beauv.]

The importance of planting seed early and having adequate moisture for germination and seedling development during the cool period of the year cannot be over emphasized. This reemphasizes the need for preparing seedbeds during the spring, summer and fall prior to planting, so that valuable moisture falling on the site during fall and winter will not be lost to evaporation by cultivating the site in the spring and use by competing species that have been inadequately controlled.

Established stands of seeded species will probably require some management (i.e. mowing or burning) to prevent deterioration of the stands, and maintain an aesthetically pleasing landscape. Miller et al. (1986) reviewed literature relative to the ecology and management of bluebunch wheatgrass. They report the species is considered sensitive to heavy grazing during the growing season. Many researchers have found the species to be sensitive to defoliation just before and during the boot stage of development, which usually occurs in early June. Regrowth after defoliation during the boot stage can be limited by high temperatures and limited soil moisture. Clipping in mid November and early March in Canadian studies did not affect the rate of tiller elongation in spring. They summarized the species' response to grazing as follows: (1) continuous grazing of individual plants throughout the growing season seriously restricts plant growth and storage of carbohydrates for maintenance of plant vigor; (2) grazing during plant dormancy has the least detrimental effect on the plant; (3) plants can withstand utilization early in the growing season if conditions allow adequate growth after grazing i.e. before the boot stage; and (4) retaining only small levels of leaf area during the boot stage has the greatest negative effect on carbohydrate storage and plant vigor.

The effect of fire on bluebunch wheatgrass appears to depend on frequency and season of burning. Little or no mortality has been reported for bluebunch wheatgrass plants when burned in the fall, and plants usually return to preburn production levels in 1 to 3 years. Spring and summer burns decrease basal area of plants and can result in high mortality. How quickly bluebunch wheatgrass responds positively to burning depends on: (1) vigor of plants before burning; (2) fire conditions; and (3) growing conditions (i.e., soil moisture) following the fire. Guidelines for prescribed burning in sagebrush ecosystems have been summarized by Wright et al. (1979) and Britton and Ralphs (1979).

Mature basin wildrye plants are hardy, long-lived perennial bunchgrasses. The culms are numerous, erect, stiff and stout from 91 cm to 244 cm tall. The Soil Conservation Service reports stands of Magnar should not be grazed or cut until late summer or fall of the second growing season. They report the species is severely damaged by overgrazing, especially in the spring. They suggest leaving a stubble height of at least 30 cm when grazing and 25 cm when cutting for hay. Repeated burning is also reported to damage the crown of the grass plant.

Our research is far from conclusive. It is difficult to access success of a seeding until 2 years after planting unless the stand fails early, like the first attempts at upper Foree and Sheeprock. Evaluations of the seedings at Foree and Sheeprock should be continued, and additional attempts should be made to establish seedings on basin wildrye site at lower Foree. We have learned of an experimental strain of basin wildrye being studied at Bridger, Montana. Seeds of this strain as well as Magnar could be used in the future. The difficulty we have encountered with establishment of Magnar is disturbing. It may be necessary to conduct additional research in the future to determine the amount of water required to establish this variety. This information could enhance the Park Service's potential for successful establishment of this valuable species on many of the areas targeted for restoration.

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