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Vegetation of chained and non-chained seedings after wildfire in Utah

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Abstract

After wildfires in 1996 in the sagebrush (*Artemisia* spp.) and pinyon-juniper (*Pinus* spp.—*Juniperus* spp.) zones of west-central Utah, the USDI-BLM attempted to reduce soil erosion and cheatgrass proliferation (*Bromus tectorum* L.) through rehabilitation treatments. We compared the vegetation of aerially seeded, chained treatments with aerially seeded but non-chained treatments for 3 years following seeding. Vegetation cover increased significantly in both treatments between the first and second year, concurrent with above-average precipitation. By the second year, seeded grasses, primarily crested wheatgrass [*Agropyron cristatum* (L.) Gaertn.] and intermediate wheatgrass [*Elymus hispidus* (Opiz) Meld. and *Elymus elongatus* (Host) Runem.], dominated the chained treatment while cheatgrass dominated the non-chained treatment. Seeded grass establishment in non-chained areas was highest beneath dead trees on steep northeast-facing slopes. The first year following the fires, frequency of most annual species and some native perennial species was higher in the non-chained than chained treatment. Native species richness and diversity declined in both treatments between the first and third year following the fires due to the loss of early-seral native annuals and probably because of climatic factors and competition from seeded grasses and cheatgrass. This study reaffirmed the utility of aerial seeding followed by chaining as a rehabilitation technique for rapid establishment of standard plant materials and suppression of cheatgrass, although the implications for soil protection were less clear. Maintenance of native biodiversity on public lands will require greater development and use of native plant materials for wildfire rehabilitation. Planning for future rehabilitation needs is important in light of continuing wildfire risks.

Key Words: Bureau of Land Management, rehabilitation, chaining, aerial seeding, plant materials, cheatgrass

Resumen

Después de los fuegos sin control ocurridos en 1996 en las zonas de "Sagebrush" (*Artemisia* spp.) y "Pinyon-Juniper" (*Pinus* spp.—*Juniperus* spp.) de la región central - oeste de Utah, el USDI-BLM intento reducir la erosión y la proliferación del "Cheatgrass" (*Bromus tectorum* L.) a través de tratamientos de rehabilitación. Comparamos la vegetación de áreas sujetas a cadeneo y siembra aérea contra áreas sin cadeneo y con siembra aérea, la comparación se realizo durante 3 años después de la siembra.. Entre el primer y segundo año la cobertura vegetal se incremento significativamente en ambos sitios, concordando con precipitación arriba del promedio. Para el segundo año los zacates sembrados, principalmente "Crested wheatgrass" [*Agropyron cristatum* (L.) Gaertn.], "intermediate wheatgrass" [*Elymus hispidus* (Opiz) Meld. y *Elymus elongatus* (Host) Runem.], dominaron en el tratamiento con cadeneo, mientras que el "Cheatgrass"domino las áreas sin cadeneo. El establecimiento de los zacates sembrados en las áreas sin cadeneo fue mayor debajo de los árboles muertos en las pendientes pronunciadas con exposición nordeste. En el primer año después de los fuegos, la frecuencia de la mayoría de las especies anuales y de algunas especies nativas perennes fue mas alta en el tratamiento sin cadeneo que en el tratamiento con cadeneo. La riqueza y diversidad de especies nativas disminuyo en ambos tratamientos entre el primer y tercer años después del fuego, debido a la perdida de especies anuales nativas de las primeras etapas serales y probablemente a causa de los factores climáticos y la competencia entre los zacates sembrados y el "Cheatgrass". Este estudio reafirma la utilidad de la siembra aérea seguida de un cadeneo como una técnica de rehabilitación para el establecimiento rápido de material vegetal estándar y la supresión del "Cheatgrass", aunque las implicaciones para la protección del suelo fueron menos claras. El mantenimiento de la biodiversidad nativa en terrenos públicos requerirá un mayor desarrollo y uso de material vegetal nativo para la rehabilitación a fuegos no prescritos. La planeación de las necesidades futuras de rehabilitación es importante por el riesgo continuo de fuegos no prescritos.

Wildfire rehabilitation via the Emergency Fire Rehabilitation program has been widely used by the USDI Bureau of Land Management (BLM) in the Intermountain West with primary purposes to reduce soil erosion, protect property and life, and prevent the spread of weeds (BLM 1999a, Roberts 1999). One rehabilitation goal on semiarid sites may be to prevent site dominance by the exotic annual cheatgrass (*Bromus tectorum* L.) by establishing perennial species (BLM 1999b, MacDonald 1999).

In areas where rangeland drills cannot be used, rehabilitation can be accomplished through aerial broadcast seeding, often fol-

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Table 1. Characteristics of study sites that burned in the summer of 1996 in west-central Utah.

Site Name	Location (Reference Marker)	Elevation (m)	Slope and Aspect	Soils
Dog Slopes	110m at 195° from Tidwell Spring exclosure, T13S R2W S19	1,650–1,690	20–34% slopes; north- to east-facing	Saxby very cobbly loam: Loamy-skeletal, mixed, mesic Lithic Xerollic Calciorthids[1]
Gilson	Section marker T13S R3W S35 T14S R3W S1 S2	1,615–1,645	4–15% slopes; mainly northeast- to southeast-facing	Borvant cobbly loam: Loamy-skeletal, carbonatic, mesic, shallow Aridic Petrocalcic Paleoxerolls[1]
Jericho	Milemarker 124, US Hwy. 6, T12S R3W S28	1,650–1,670	4–16% slopes; east, south-, and west-facing	Jericho gravelly fine sandy loam: Loamy-skeletal, mixed, mesic, shallow Xerollic Durorthids[1]
Paul Bunyan	Near Paul Bunyan's Woodpile road, T12S R3W S23	1,800–1,810	5–11% slopes; mainly west- and south-facing	Jericho gravelly fine sandy loam: Loamy-skeletal, mixed, mesic, shallow Xerollic Durorthids[1]
Railroad	151m at 195° from section marker T12S R3W S15 S16 S21 S22	1,670–1,680	5-7% slopes; north-, south-, and west-facing	Wales loam: Fine-loamy, mixed (calcareous), mesic Xeric Torrifluvents[1]
Twin	Quarter-section marker T25S R7W S29 S32	1,800–1,810	1–6% slopes; north- to northeast-facing	Kessler-Penoyer very cobbly loam: Fine-silty, carbonatic, mesic XerollicCalciorthids; and/or coarse-silty, mixed (calcareous), mesic Typic Torriorthents[2]

[1]Trickler and Hall (1984)
[2]Stott and Olsen (1976)

lowed by chaining (Vallentine 1989, BLM 1999b, MacDonald 1999). Chaining has been widely used on rangelands to eliminate unwanted trees and brush (Vallentine 1989), but in wildfire rehabilitation its primary role is to create a suitable seedbed including coverage of seed by soil (BLM 1999b). Although the BLM has accumulated much corporate knowledge of wildfire rehabilitation using chaining through years of practical experience, few formal studies have been conducted. See Clary (1988) for some Utah chaining and seeding study examples and results.

This paper presents a comparative study in which vegetation of chained and nonchained seedings was monitored for 3 years following 1996 Utah wildfires. Controversy over the impact of chaining treatments on archeological sites, wilderness resources, and native vegetation dynamics following these fires stimulated this research. Our objective was to document the effects of these rehabilitation treatments, particularly in relation to seeded plant establishment, exotic annual suppression, and consequences to native species.

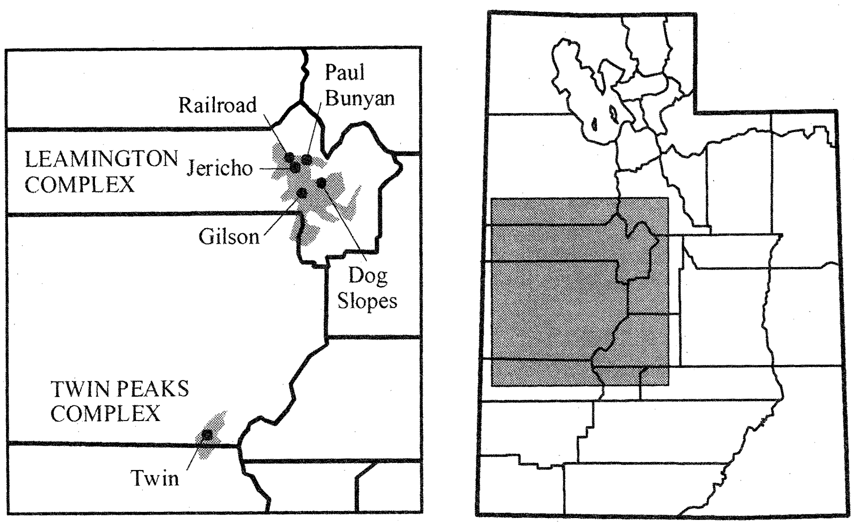

Fig. 1. Location of 1996 fire complexes (shaded) and rehabilitation study sites in west-central Utah.

Study Area and Rehabilitation Description

The Twin Peaks Complex fire was ignited by lightning on 5 July 1996 and was controlled on 12 July 1996 (BLM, personal communication). The area affected by this fire lies between 38° 30'–45''N and 113° 35'–50'W in Millard and Beaver counties, Utah (Fig. 1; Table 1), primarily between 1,580-1,950 m elevation, on plains and low ridges composed primarily of basalt flows and alluvium (Hintze 1975). Pre-burn vegetation was dominated by mature Wyoming big sagebrush [*Artemisia tridentata* var. *wyomingensis* (Beetle & A. Young) Welsh] and Utah juniper [*Juniperus osteosperma* (Torr.) Little], in a precipitation regime averaging 30 to 41 cm per year over a 30-year period (USDA-NRCS 1999). Pre-burn understory vegetation varied but included substantial amounts of cheatgrass.

Another fire, the Leamington Complex, occurred in an area about 120 km to the north of the Twin Peaks Complex, in Juab county, Utah, between 39° 24'-50'N and 111° 50'–112° 20'W (Fig. 1; Table 1). The Leamington Complex fire began with a lightning strike on 1 August 1996 and was controlled on 17 August 1996 (BLM, personal communication). Most of this fire occurred between 1,520–2,100 m elevation, on topography characterized by alluvial plains, foothills, and fault-block mountains composed of volcanic rocks and limestone (Hintze 1975). Pre-burn vegetation was a mosaic of seral stages of sagebrush steppe and pinyon (*Pinus* spp.)-juniper and juniper woodlands as well as stands of cheatgrass and seeded grasses. Precipitation in this area ranges from a 30-year average of 25 to 30 cm per year in lower valley areas to 41 to 46 cm per year on lower mountain slopes (USDA-NRCS 1999).

Seed mixes were prepared primarily using 'Hycrest' and 'Nordan' crested wheatgrass [(*Agropyron cristatum*(L.) Gaertn.)], 'Oahe' intermediate wheatgrass [*Elymus hispidus* (Opiz) Meld.], 'Luna' pubescent wheatgrass [*Elymus hispidus* (Opiz) Meld.], 'Alkar' tall wheatgrass [*Elymus elongatus* (Host) Runem.], 'Bozoisky' Russian wildrye (*Elymus junceus* Fisch.), 'Magnar' Great Basin wildrye (*Elymus cinereus* Scribn. & Merr.), 'Lincoln' smooth brome (*Bromus inermis* Leysser), 'Ladak' alfalfa (*Medicago sativa* L.), and fourwing saltbush [*Atriplex canescens* (Pursh) Nutt.]. Seed mix composition, seeding rates, and timing of application differed for different locations and treatments (Table 2). An Ely anchor chain was used at all sites considered in this study. The Ely chain is a modification of the standard anchor chain (rail segments are welded to some of the chain links to provide added weight and additional soil disturbance—Vallentine 1989).

Aerial seeding followed by chaining was carried out as weather conditions permitted from autumn 1996 until 31 March 1997, when chaining was halted by a temporary court restraining order (BLM, personal communication). This was the result of legal proceedings led by citizens concerned with the impact of these chaining treatments on archeological sites (Haase 1983) and on the integrity of wilderness resources and native vegetation (SUWA 1997, SUWA personal communication). At the time of this order, aerial seeding treatments had been completed but chaining treatments were only partially completed and were not pursued further by the Utah BLM during that year (BLM, personal communication). Thus, some lands had been seeded and chained and some had been seeded but not chained. No further chaining occurred on the 1996 burns until 1998 after legal restraints were lifted. Livestock grazing was restricted from rehabilitated sites for 2 growing seasons following treatment.

Methods

During the summer of 1997, we selected 6 study sites, 5 within the burned area of the Leamington Complex, and 1 within the Twin Peaks Complex (Fig. 1; Table 1). Sites were selected based on accessibility and the presence of treatments of interest on comparable topographic settings. All sites included a chained treatment (aerially seeded followed by Ely chaining) adjacent to an aerially seeded, non-chained treatment. Site selection resulted in 5 different seed mixes being represented (Table 2). The non-chained treatment area at the Railroad site was inadvertently reseeded and chained by the BLM during a 1998-1999 operation. We relocated plot markers following this chaining and collected plot data in 1999—see Ott (2001) for further details.

At 3 sites, cadastral survey markers were used as reference points. Metal rebar stakes were placed to mark reference points at sites lacking such markers. Transect lines were extended directly from the reference point, following cardinal directions, or otherwise arranged systematically within the different treatment areas of each site. Plots were established at regular intervals along the transect lines, with 4 plots per treatment at each site. A rebar was placed to mark each plot at tape-measured intervals of 50 m (Twin, Gilson, Dog Slopes, and Railroad sites), or 60 m (Jericho and Paul Bunyan sites). This rebar served as the center of a circular plot of radius 5.6 m (100 m^2) and also served as the southwest corner of a square-shaped, 1 m^2 plot (McArthur and Sanderson 1996). The larger plot allowed greater scope, while the smaller plot allowed greater precision of data collected. Data were collected each year for 3 consecutive years (July–August 1997, June-early July 1998, and late June-early August 1999).

We used the ocular relevé methods of Shimwell (1971) and McArthur and Sanderson (1996) to estimate cover of vascular plants, bare soil, litter, rock (> 2 cm diameter), and cryptogams (biological soil crusts and non-vascular plants) in both large (100 m^2) and small (1 m^2) plots. Foliar vascular plant cover percent was estimated first, and the remaining plot area was then assigned to the other categories so that the total of these 5 categories always equaled 100%. Litter was defined as any herbaceous material from a previous growing season, and any dead woody material in contact with the surface of the ground, including fallen branches and bases of dead trees.

Foliar cover was estimated for each vascular plant species having canopy within

Table 2. Aerial applied seed mixtures and seeding rates for 1996–1997 rehabilitation at sites that burned in the summer of 1996 in west-central Utah (Information supplied by the Fillmore Field Office, USDI BLM).

Plant Material[1]	Seeding Rate (kg/ha^{-1})
Dog Slopes Site	
Crested wheatgrass ('Hycrest')	5.0
Pubescent wheatgrass[2]	3.4
Russian wildrye ('Bozoisky')	2.4
Tall wheatgrass[2]	1.7
Crested wheatgrass ('Fairway')	0.4
Total	12.9
Gilson Site	
Crested wheatgrass ('Hycrest')	3.4
Smooth brome ('Lincoln')	2.2
Russian wildrye ('Bozoisky')	2.2
Tall wheatgrass[2]	2.2
Fourwing saltbush[2]	1.1
Total	11.2
Jericho Site	
Crested wheatgrass ('Hycrest')	3.5-4.5[3]
Russian wildrye ('Bozoisky')	2.4-3.4
Tall wheatgrass[2]	2.2
Smooth brome (Lincoln)	0-2.0
Great Basin wildrye[2]	0-1.1
Fourwing saltbush[2]	1.1
Total	11.2-12.3
Paul Bunyan Site	
Crested wheatgrass ('Hycrest')	4.5
Russian wildrye ('Bozoisky')	3.4
Tall wheatgrass[2]	2.2
Fourwing saltbush[2]	1.1
Total	11.2
Railroad Site	
Crested wheatgrass ('Hycrest')	3.5
Russian wildrye ('Bozoisky')	2.4
Tall wheatgrass[2]	2.2
Smooth brome ('Lincoln')	2.0
Great Basin wildrye[2]	1.1
Fourwing saltbush[2]	1.1
Total	12.3
Twin Site	
Crested wheatgrass ('Hycrest')	6.7
Russian wildrye ('Bozoisky')	4.1
Pubescent wheatgrass ('Luna')	3.2
Crested wheatgrass ('Nordan')	2.8
Alfalfa ('Ladak')	0.3
Total	17.3

[1]For scientific names see Table 3.
[2]Cultivar information not available.
[3]The Jericho study site included two seed mixes on opposite sides of U.S. Highway 6, the same mixes as applied to the Paul Bunyan and Railroad sites.

Table 3. Frequency of species by treatment and year in 2 plot sizes at sites burned in the summer of 1996 in west-central Utah. Only species with frequency of 4 or greater in any given year across both treatments are shown [See Ott (2001) for additional detail].

		All Sites						Railroad Site	
	No.	Chained			Non-chained			Late-chained[1]	
Species[2]	Sites	1997	1998	1999	1997	1998	1999	1998	1999
Seeded Shrubs and Forbs									
Atriplex canescens (Pursh) Nutt. (fourwing saltbush)	4[3]	13 (1)[4]	13 (1)	13 (1)	4	1	2	0	0
Medicago sativa L. (alfalfa)	4	3	5	2	1	3	6	0	4
Seeded Grasses									
Agropyron cristatum (L.) Gaertn. (crested wheatgrass)[2]	6	23 (18)	23 (18)	23 (20)	20 (7)	20 (8)	21 (12)	4	4 (2)
Bromus inermis Leysse (smooth brome)	4	15 (8)	15 (7)	15 (8)	11 (3)	12 (5)	16 (8)	4 (1)	4 (4)
Elymus hispidus (Opiz) Meld. (intermediate wheatgrass)[2,5]	6	23 (17)	22 (15)	23 (17)	17 (4)	16 (5)	22 (8)	4 (1)	4 (3)
Elymus junceus Fisch. (Russian wildrye)	6	8	22 (8)	19 (4)	6	14 (3)	13 (3)	2	2
Exotic Grasses									
Bromus japonicus Thunb. ex Murray (Japanese brome)	5	11	5 (1)	6 (1)	2	6 (1)	3	0	1
Bromus tectorum L. (cheatgrass)	6	23 (16)	23 (20)	24 (20)	24 (17)	24 (22)	24 (24)	4 (4)	4 (4)
Native Grasses									
Elymus elymoides (Raf.) Swezey (bottlebrush squirreltail)	6	16 (4)	15 (3)	13 (5)	18 (3)	19 (4)	20 (4)	4 (2)	4 (2)
Elymus smithii (Rydb.) Gould (western wheatgrass)	2	4 (1)	4 (2)	4 (2)	2	1	1	0	0
Elymus spicatus (Pursh) Gould (bluebunch wheatgrass)	4	10 (5)	11 (5)	10 (4)	13 (9)	14 (8)	13 (9)	0	0
Poa fendleriana (Steudel) Vasey (muttongrass)	5	7 (3)	7 (4)	9 (3)	10 (6)	12 (5)	8 (4)	3	0
Poa secunda Presl (Sandberg bluegrass)	1	4 (2)	4 (2)	4 (1)	4 (4)	4 (1)	3 (1)	0	0
Stipa hymenoides R. & S. (Indian ricegrass)	6	17 (3)	16 (3)	15 (3)	17 (4)	18 (5)	17 (3)	3	3
Exotic Forbs									
Alyssum desertorum Stapf (desert alyssum)	6	14 (1)	16 (7)	18 (7)	17 (6)	18 (14)	20 (15)	2 (2)	2 (1)
Camelina microcarpa Andrz. ex DC. (falseflax)	3	4	6 (2)	8 (3)	3 (2)	6 (2)	8 (4)	0	0
Chenopodium album L. (lambsquarter)	4	4	0	0	1	0	0	0	0
Descurainia sophia (L.) Webb ex Prantl (tansymustard)	3	0	0	2	0	3	4	0	0
Erodium cicutarium (L.) L'Her (storksbill)	2	1	2	1	2	3 (2)	3 (2)	0	0
Lactuca serriola L. (prickly lettuce)	6	11 (1)	20 (9)	13 (3)	22 (2)	21 (13)	24 (12)	1	4 (4)
Malcolmia africana R. Br. in Ait. (African mustard)	3	5	3	0	5 (1)	4 (2)	1 (1)	0	0
Ranunculus testiculatus Crantz (bur buttercup)	3	5 (3)	1 (1)	2 (1)	9 (7)	2 (1)	4 (3)	0	0
Salsola pestifer A. Nels. (Russian thistle)	5	4	2	2	1	4 (1)	3 (1)	0	0
Sisymbrium altissimum L. (tumblemustard)	5	7 (1)	18 (10)	16 (6)	6 (1)	18 (12)	18 (10)	4 (2)	4 (4)
Tragopogon dubius Scop. (yellow salsify)	6	7	7	8	8	9 (2)	20 (3)	0	3
Native Annual Forbs									
Camissonia boothii (Dougl.) Raven (Booth's camissonia)	3	1	1	0	7 (2)	2	0	0	0
Descurainia pinnata (Walter) Britt. (pinnate tansymustard)	6	14 (3)	20 (10)	2 (1)	19 (6)	18 (5)	0	3 (1)	0
Eriogonum deflexum Torr. in Ives (skeleton buckwheat)	5	4	1	0	9 (3)	3 (1)	2	0	0
Eriogonum maculatum Heller (spotted buckwheat)	2	1	0	0	6	0	0	0	0
Gilia giliodes (Benth.) Greene (collomia gilia)	1	1	0	0	3 (3)	0	0	0	0
Gilia inconspicua (J.E. Sm.) Sweet (floccose gilia)	6	19 (9)	11 (7)	4	24 (16)	11 (6)	7 (1)	1	3
Helianthus annuus L. (common sunflower)	5	12 (1)	5	3	3	3	4 (1)	0	2 (1)
Lappula occidentalis (Wats.) Greene (western stickseed)	3	1	2	0	9 (1)	1	0	0	0
Mentzelia albicaulis (Hook.) T.& G. (whitestem blazingstar)	4	8	0	0	9 (3)	0	0	0	0
Microsteris gracilis (Hook.) Greene (little polecat)	2	2 (1)	0	0	4 (1)	1 (1)	0	0	0
Nicotiana attenuata Torr. ex Wats. (coyote tobacco)	5	12 (1)	0	0	14 (1)	3	1	0	0
Phacelia ivesiana Torr. in Ives (Ives' phacelia)	4	6	0	0	8	0	0	0	0
Native Perennial Forbs and Shrubs									
Arenaria fendleri Gray (Fendler's sandwort)	1	3 (1)	3 (1)	4 (2)	3 (3)	3 (3)	3 (3)	0	0
Argemone munita Dur. & Hilg. (prickly-poppy)	4	4	4	4	6 (1)	6 (1)	5	0	0
Artemisia tridentata Nutt. (big sagebrush)	4	0	0	0	5	2	2	1	0
Astragalus calycosus Torr. ex Wats. (Torrey's milkvetch)	4	3	4	3	6 (1)	7	4 (1)	1	0
Astragalus eurekensis Jones (Eureka milkvetch)	4	6 (2)	7 (1)	5 (1)	9 (2)	8 (4)	6 (3)	0	0
Astragalus lentiginosus Dougl. ex Hook (freckled milkvetch)	4	7	6	2	9 (1)	11	4	2	1
Calochortus nuttallii T.& G. in Beckwith (sego lily)	4	16 (1)	11 (1)	7 (4)	14 (3)	11 (2)	7 (1)	2	0
Caulanthus crassicaulus (Torr.) Wats. (spindlestem)	1	2	2	1	2 (1)	3 (1)	2	0	0
Chaenactis douglasii (Hook.) H. & A. (Douglas' dustymaiden)	6	9 (1)	10 (1)	1	12 (1)	10 (1)	3	1	0
Crepis acuminata Nutt. (mountain hawksbeard)	2	2	1	1	3	2	3	0	0
Crepis occidentalis Nutt. (western hawksbeard)	2	4 (1)	5 (1)	4 (1)	4 (2)	4 (2)	4 (2)	0	0
Cryptantha humilis (Greene) Payson (dwarf cryptanth)	3	2	3	2	4	6	5	0	0

(Continued on page 85)

Table 3. Continued.

Species[2]	No. Sites	All Sites: Chained 1997	Chained 1998	Chained 1999	Non-chained 1997	Non-chained 1998	Non-chained 1999	Railroad Site: Late-chained[1] 1998	Late-chained[1] 1999
Erigeron aphanactis (Gray) Greene (hairy daisy)	1	2	1	1	4	4	4	0	0
Erigeron engelmannii A. Nels. (Engelmann's daisy)	3	0	3	1	0	2	2	1	1
Gutierrezia sarothrae (Pursh) Britt. & Rusby (broom snakeweed)	3	5	4	5	6 (1)	6	7 (1)	0	0
Machaeranthera canescens (Pursh) Gray (Hoary aster)	4	4	4	2	7	8	6	0	0
Opuntia polyacantha Haw (central pricklypear)	3	4 (1)	3 (1)	4	0	0	1 (1)	0	0
Phlox austromontana Cov. (desert phlox)	3	8 (2)	7 (1)	7 (1)	6 (3)	6 (4)	6 (4)	0	0
Phlox longifolia Nutt. (longleaf phlox)	5	12 (8)	9 (8)	7 (6)	12 (5)	8 (3)	4 (2)	1	2
Physaria chambersii Rollins (Chamber's twinpod)	3	4	3	3	2	2	1	0	0
Senecio multilobatus T.& G. (Uinta groundsel)	5	3	2	2	2	3	2	1	1
Sphaeralcea coccinea (Nutt.) Rydb. (common globemallow)	1	4 (1)	4	4	4 (2)	4 (3)	4 (3)	0	0
Sphaeralcea grossulariifolia (H. & A.) Rydb. (gooseberry-leaf globemallow)	3	10 (1)	10 (1)	11 (1)	8	8	8	4	4
Streptanthus cordatus Nutt. ex T. & G. (twistflower)	4	9 (1)	6	2	12	6	2	2	2

[1]Late-chained refers to the Railroad site non-chained treatment that was reseeded and chained between 1998 and 1999. Note that the frequency values in these columns are also part of the total frequency values shown in the 1998 and 1999 columns of the non-chained treatment for all sites.
[2]Scientfic nomenclature follows Welsh et al. (1993). In that treatment, *Agropyron desertorum* (Link) Schultes is synonymized with *A. cristatum* and both *A. intermedium* (Host) Beauv. And *A. trichophorum* (Link) Richter are treated as *Elymus hispidus*.
[3]Number of sites where species was recorded, of 6 sites total.
[4]Value on left is frequency in 100 m2 plots; value in parentheses is frequency in 1 m2 plots, shown if greater than zero. Maximum frequency value is 24 for all sites, 4 for the Railroad site.
[5]Includes tall wheatgrass [*Elymus elongatus* (Host) Runem.] because we could not distinguish it from E. hispidus at the time of data collection.

plot boundaries. Species nomenclature followed Welsh et al. (1993). We did not attempt to distinguish varieties of seeded species; all varieties of crested and desert wheatgrass were placed together and referred to as crested wheatgrass, and all varieties of intermediate, pubescent, and tall wheatgrass where combined and referred to as intermediate wheatgrass. For the large plots, each species was assigned a cover class, following Daubenmire (1959) with an additional class for less than 1% cover (McArthur and Sanderson 1996). For the small plots, percent cover of each species was estimated to the nearest whole number. We combined individual species into 7 groups of interest, based on growth form, longevity, and origin (Table 3). "Exotic" species, principally cheatgrass, were neither native to the region nor derived from the fire rehabilitation seed mixes but were present in the seed bank. Cover values of species in the same group within the same plot were added together to create total cover values for these groups. For the large plots, total cover values were calculated using the midpoints of cover classes. The total number of species (species richness) and the number of native species were tabulated for each large plot, as were total and native species diversity using the Shannon-Wiener Index (Krebs 1999). Cover was used as a measure of species abundance in diversity calculations.

We compared chained and non-chained treatments using SAS PROC MIXED in a mixed model, first order autoregressive repeated measures analysis (SAS 1990). This statistical approach adjusts standard errors so that comparisons can be made across factors (Littell et al. 1996). Large and small plot sizes were analyzed separately. All combinations of these 2 treatments, 6 sites, and 3 years were included in this analysis, except the 1999 Railroad site non-chained treatment (which had lost its non-chained status by 1999, as described above). The variables analyzed were species richness, species diversity, and percent cover of selected species and categories. Percent cover values were transformed by taking the arcsine of the square root (Steel and Torrie 1960). Site and the interaction of site with treatment and year were treated as random effects, while treatment, year, and their interaction were treated as fixed effects. Tukey's HSD procedure (Steel and Torrie 1960) was used to test differences among treatment, year, and treatment by year means. We chose the value of $P < 0.05$ as the level of significant differences.

With site as a random factor in the mixed model, statistical inferences can be made for the larger set of sites from which the sites of this study were drawn. Differences between sites and their interaction with treatment and year are incorporated into the error terms of the mixed model (Littell et al. 1996). Thus site differences were not analyzed explicitly, although site means were examined visually for each treatment and year.

Results

Species Frequencies, Richness, and Diversity

A total of 117 species were recorded in 48 plots over the course of 3 years, not including unidentified species or species within taxa that were lumped. Groups with the most recorded species were native perennial forbs and shrubs (49 species), native annual forbs (27 species), exotic forbs (mostly annual, 16 species), and native grasses (mostly perennial, 8 species). Species recorded more than 4 times in large plots during the course of the study are shown in Table 3. Species frequencies in both large plots and small plots are shown in Table 3, allowing for visual assessment of species importance and trends at 2 different scales. In the text that follows we use common names; we refer readers to Table 3 for scientific names and authorities.

The most frequently recorded species in 1997 (recorded in 40 or more of 48 large plots) were cheatgrass, crested wheatgrass, intermediate wheatgrass, and floccose gilia (Table 3). Frequency of seeded species was greater with chaining in 1997, but most other species were unaffected by chaining. Annual forbs had higher frequency in the non-chained treatment in 1997. Over the 3-year study seeded grasses increased in frequency in both large and small plots in the non-chained treatment. Low frequency of Russian wildrye in 1997 reflects our failure to properly identify this

Table 4. Mean species richness and species diversity of 100 m² plots, by treatment and yea at sites burned in the summer of 1996 in west-central Utah.

	Chained			Non-chained		
	1997	1998	1999	1997	1998	1999[1]
Species richness (all spp.)	20[AB2]	18[ABC]	15[C]	22[A]	19[ABC]	17[B]
Species richness (native spp.)	12[AB]	10[CD]	7[D]	15[A]	11[BC]	8[D]
Shannon-Wiener index (all spp.)	0.91[AB]	0.77[ABC]	0.69[C]	0.87[A]	0.62[ABC]	0.62[B]
Shannon-Wiener index (native spp.)	0.82[AB]	0.73[CD]	0.61[D]	0.92[A]	0.75[BC]	0.55[D]

[1]Means were based on 6 sites, except for the 1999 non-chained treatment that was based on 5 sites (Railroad site excluded).
[2]Means within rows followed by the same letter were not significantly different at P < 0.05 as determined by Tukey's HSD in a mixed-model, first-order autoregressive repeated measures analysis.

species before flowering. Cheatgrass occurred in nearly all large plots from the beginning of the study, but increased in the small plots over time, indicating a spatial expansion of cheatgrass within the large plots. Two exotic forbs (lambsquarter and African mustard) decreased in both treatments, whereas 4 others (desert alyssum, falseflax, tansymustard, and yellow salsify) increased in both treatments. Frequency of prickly lettuce and tumblemustard peaked in 1998, while frequency of bur buttercup was lowest in 1998. Frequency of native grass species fluctuated among years without clear trends. Most native annual forbs decreased in frequency over time in both treatments. The native perennial forb/shrub group also included some species that decreased in both treatments over time; for example, sego lily, freckled milkvetch, longleaf phlox, and twistflower. Big sagebrush, which occurred as seedlings, was not present in the chained treatment and was lost from 3 non-chained plots between 1997 and 1998 (Table 3).

Total species richness was highest in 1997, when 94 species occurred in the chained plots and 93 in the non-chained plots (Table 4). Within each treatment, species richness was significantly lower in 1999 than 1997. Within years, treatment did not significantly affect species richness, except that in 1999 the mean species richness of the non-chained was slightly higher than the chained treatment. When only native species were considered, mean species richness did not differ between treatments for a given year, although native species richness decreased significantly in both treatments between 1997 and 1999. Responses for species diversity (Shannon-Wiener index) were identical to those of species richness, for native species as well as total species (Table 4).

Percent Cover of Categories and Species

In general, mean cover values were similar for small and large plots and patterns of statistical significance were similar. The most noticeable variation between plot sizes was for vascular plants and bare soil, where the difference in mean percent cover between large and small plots was as high as 12–14% (Table 5). In the text that follows, mean values are written as a range from the mean of one plot size to the mean of another, unless otherwise specified.

Mean values for total vascular plant cover did not differ significantly between treatments within years, but increased significantly in both treatments between 1997 and 1998 (Table 5). The increase in vascular plant cover between 1997 and 1998 in the chained treatment was due primarily to seeded grasses, while the increase in the non-chained treatment was due primarily to exotic grasses (Table 6). In 1997, total cover of seeded grasses was 10-12% in the chained and 2% in the non-chained treatment, a difference that was significant in the large plots (P = 0.01) but not the small plots (P = 0.16). Total cover of seeded grasses in the chained treatment increased significantly to 27–30% in 1998, and maintained that high cover (31-33%) in 1999 in contrast to the non-chained treatment cover values, 4–7% in 1998 and 8–11% in 1999. Cover of exotic grasses (almost exclusively cheatgrass) increased significantly between 1997 (18-22%) and 1998 (42-48%) in the non-chained but not the chained treatment. Exotic grass cover was significantly higher in the non-chained large plots in 1998 and 1999.

Of the seeded grasses, crested wheatgrass and intermediate wheatgrass were dominant with about equal amounts of cover within treatments and years. In the chained treatment, cover of each of these 2 species was 4–6% in 1997, rising to 12–14% in 1999 (Table 6). This increase was significant for crested but not intermediate wheatgrass. In the non-chained treatment, mean cover of each of these 2 species remained between ca. 1–4% and was not significantly different among years. Cover of smooth brome, seeded at only 4 of the 6 study sites, increased significantly in the large plots of the chained treatment between 1997 (1%) and 1998 (5%). At individual sites where smooth brome had been seeded, cover was as high as 9–10% in the chained treatment. Russian wildrye was present at all sites but was not accurately recorded until 1998. Lower cover of Russian wildrye in 1999 resulted from preferential grazing by livestock. In 1998, cover of Russian wildrye was slightly greater in the chained treatment (4% in large plots) than the non-chained treatment (<1% in large plots) (Table 6). Considering the high seeding rates of Russian wildrye at some sites (Table 2), establishment of this species was poor. Basin wildrye, which was seeded at 2 sites, was not conclusively identified at any of the plots or sites.

Although native perennial grasses were subordinate to seeded grasses and cheatgrass over the study area as a whole, they dominated certain sites and plots. Cover of western wheatgrass, a rhizomatous species, appeared to be higher in the chained (1–5%) than the non-chained treatment (<1%) (Table 6), but only because more chained plots fell within its patches. At 1 chained plot at the Gilson site, cover of western wheatgrass was in

Table 5. Mean percent cover of cover categories, by treatment and year, in 2 plot sizes at sites burned in the summer of 1996 in west-central Utah.

	Chained			Non-chained		
	1997	1998	1999	1997	1998	1999[1]
Vascular Plants	38[B] (27[b])[2]	65[A] (51[ac])	59[A] (52[ac])	41[B] (34[bc])	71[A] (61[a])	62[A] (53[a])
Bare Soil	40[A] (52[a])	22[B] (34[bc])	20[B] (26[bcd])	37[A] (41[ac])	16[B] (21[bc])	14[B] (15[de])
Litter	11 (10)	7 (8)	15 (16)	8 (9)	5 (7)	15 (20)
Rock (>1 cm)	11 (11)	6 (7)	6 (6)	14 (17)	9 (11)	9 (12)
Cryptogams	+ (+)	+ (+)	+ (+)	1 (+)	+ (+)	+ (+)

[1]Means were based on 6 sites, except for the 1999 non-chained treatment that was based on 5 sites (Railroad site excluded).
[2]Value on left is mean percent cover for 100 m² plots; value in parentheses is mean percent cover for 1 m² plots. Means within rows followed by the same letter of the same case were not significantly different at P < 0.05 as determined by Tukey's HSD in a mixed-model, first-order autoregressive repeated measures analysis.
+ indicates mean values less than 0.5; other values are rounded to the nearest whole number.

the 26–51% class in 1997 and 1999, and the 51–75% class in 1998. Bluebunch wheatgrass cover remained between 2-4% in the chained treatment, but increased annually in the non-chained treatment. In the small plots, the change in bluebunch wheatgrass cover from 4% in 1997 to 14% in 1999 was significant. The Dog Slopes site had the highest cover of bluebunch wheatgrass and accounted for most of this trend. Mean percent cover of bottlebrush squirreltail, Sandberg bluegrass, muttongrass, and Indian ricegrass was about 1% or less in both treatments during the study. Total cover of native grasses ranged from 8–10% in the large plots and 4–15% in the small plots, but was not significantly different between treatments or among years.

Cover for most forbs and shrubs mirrored average frequency; only a few forbs consistently occurred with greater than 1% cover. Total cover of exotic forbs was significantly greater in the non-chained treatment in 1998 (ca. 8%) than the chained treatment in 1997 and 1999 (ca. 0–4%; Table 6). The most important species in this category was tumblemustard, which did not differ significantly in cover between treatments within years, but increased significantly in the non-chained treatment between 1997 (< 0.5%) and 1998 (5%). Native annual forbs cover was 4–8% in 1997, decreasing significantly in both treatments to 1% or less in 1998 and 1999. Floccose gilia accounted for about half of the cover of native annual forbs in the 1997 non-chained treatment. Total cover of native perennial forbs and shrubs was not significantly different between treatments within years and did not change significantly over time except in the large plots of the non-chained treatment, where a significant decrease occurred from 6% in 1997 to 4% in 1999. Cover of seeded shrubs and forbs was low and was not significantly different between treatments or among years. Mean cover of fourwing saltbush in the chained treatment averaged about 1% across 3 years (Table 6). Fourwing saltbush was present in fewer plots in the non-chained than in the chained treatment, and cover never exceeded 1% in any plot. Alfalfa was a component of the seed mix of the Twin site (Table 2), but cover never exceeded 1% in any plot.

Discussion

Seeded Plant Establishment

The enhancement of establishment through chaining is a consequence of seed burial, the modification of soil physical properties, and development of safe sites. Crested wheatgrass, intermediate wheatgrass, smooth brome and other grasses with seeds of medium to large size tend to germinate and establish successfully when buried at depths of 1–3 cm (Hull 1966, Keller 1979, Vallentine 1989). Germination of uncovered seed and establishment of seedlings may be poor because of inadequate soil contact, dessication, or rooting difficulty (Vallentine 1989, Winkel et al. 1991). Exposed seed may also be lost through predation (Nelson et al. 1970). In contrast, deep burial can inhibit seedling emergence and survival (Vallentine 1989, Lawrence et al. 1991). Chaining results in irregular seed burial, which can be considered a disadvantage of this technique compared to drilling (BLM 1999b). Alternatively, the multiple microsites and seed burial depths generated by chaining can be advantageous for the establishment of mixes containing seeds with different depth requirements (Stevens 1999). Loosening soil surfaces by chaining may also increase aeration, porosity, and water infiltration, which are beneficial soil properties of plowed soils (Wood et al. 1982, Cluff et al. 1983).

The greatest response of seeded grasses to chaining occurred at the Twin Peaks site, on soils derived from basalt cobbles and loess. Chaining at this site resulted in cobbles being overturned and scattered, which initially appeared to be detrimental in terms of soil protection, yet resulted in near 50% foliar cover of seeded grass by 1998.

Where aerial seeding was not followed

Table 6. Mean percent cover of species groups and selected species, by treatment and year, in 2 plot sizes at sites burned in the summer of 1996 in west-central Utah.

	Chained			Non-chained		
	1997	1998	1999	1997	1998	1999[1]
Total seeded shrubs and forbs	**1 (1)**[2]	**1 (1)**	**1 (1)**	**+ (0)**	**+ (0)**	**+ (0)**
Alfalfa[3]	+ (0)	+ (0)	+ (0)	+ (0)	+ (0)	+ (0)
Fourwing saltbush	1 (1)	1 (1)	1 (1)	+ (0)	+ (0)	+ (0)
Total seeded grasses	**12^{B} (10^{b})**[4]	**30^{A} (27^{a})**	**31^{A} (33^{a})**	**2^{C} (2^{b})**	**4^{BC} (7^{b})**	**8^{BC} (11^{b})**
Crested wheatgrass	4^{C} (4^{C})	8^{B} (8^{b})	12^{A} (14^{a})	1^{D} (1^{c})	1^{CD} (2^{c})	4^{CD} (4^{c})
Intermediate and tall wheatgrass	6^{AB} (6^{ab})	10^{AB} (13^{ac})	13^{A} (14^{a})	1^{B} (1^{b})	1^{B} (1^{b})	2^{B} (3^{b})
Russian wildrye	$+^{B}$ (0^{b})	4^{A} (2^{a})	1^{B} (1^{ab})	$+^{B}$ (0^{ab})	$+^{B}$ (1^{ab})	$+^{B}$ (1^{ab})
Smooth brome	1^{B} (1^{a})	5^{A} (2^{a})	4^{AB} (4^{a})	$+^{B}$ (1^{a})	1^{AB} (2^{a})	2^{AB} (2^{a})
Total exotic grasses	**10^{B} (8^{b})**	**18^{B} (17^{bc})**	**14^{B} (16^{bd})**	**22^{B} (18^{b})**	**48^{A} (42^{ac})**	**35^{A} (27^{acd})**
Cheatgrass	9 (8)	18 (17)	14 (16)	22 (18)	48 (42)	35 (27)
Total native grasses	**8^{A} (4^{a})**	**8^{A} (7^{a})**	**10^{A} (6^{a})**	**7^{A} (5^{a})**	**10^{A} (10^{a})**	**14^{A} (15^{a})**
Bluebunch wheatgrass	2^{A} (2^{ab})	4^{A} (2^{ab})	3^{A} (3^{ab})	4^{A} (4^{b})	6^{A} (8^{ab})	10^{A} (14^{a})
Bottlebrush squirreltail	1 (1)	1 (1)	+ (1)	1 (+)	1 (+)	1 (1)
Indian ricegrass	1 (+)	1 (+)	1 (+)	1 (1)	2 (1)	2 (1)
Bluegrass spp.	+ (+)	+ (1)	+ (+)	1 (1)	1 (1)	+ (+)
Western wheatgrass	3 (2)	2 (2)	4 (2)	+ (0)	+ (0)	+ (0)
Total exotic forbs	**2^{B} ($+^{c}$)**	**5^{AB} (6^{ab})**	**2^{BC} (4^{bc})**	**5^{AB} (5^{abc})**	**8^{A} (8^{a})**	**7^{AC} (4^{abc})**
Desert alyssum	+ (+)	1 (+)	+ (+)	1 (1)	+ (2)	2 (1)
Falseflax	+ (0)	+ (+)	+ (+)	1 (1)	+ (+)	+ (+)
Prickly lettuce	1 (+)	1 (2)	+ (+)	1 (3)	1 (1)	1 (+)
Tumblemustard	$+^{B}$ ($+^{ab}$)	2^{AB} (3^{ab})	1^{AB} (3^{ab})	$+^{B}$ ($+^{b}$)	5^{A} (5^{a})	2^{AB} (1^{ab})
Total native annual forbs	**5^{A} (4^{ab})**	**1^{B} (1^{bc})**	**+B ($+^{c}$)**	**8^{A} (6^{a})**	**1^{B} (1^{bc})**	**$+^{B}$ ($+^{c}$)**
Common sunflower	1 (+)	+ (0)	+ (0)	+ (0)	+ (0)	+ (0)
Coyote tobacco	2 (+)	0 (0)	0 (0)	1 (+)	+ (0)	+ (0)
Floccose gilia	1 (4)	+ (+)	+ (0)	4 (3)	+ (+)	+ (+)
Total native perennial forbs and shrubs	**4^{ABC} (1^{a})**	**3^{ABC} (1^{a})**	**2^{BC} (1^{a})**	**6^{A} (3^{a})**	**5^{AB} (4^{a})**	**4^{C} (3^{a})**
Milkvetch spp.	+ (+)	+ (+)	+ (+)	1 (+)	1 (+)	+ (+)
Phlox spp	1 (+)	1 (+)	+ (+)	1 (1)	+ (1)	+ (1)
Globemallow spp.	1 (+)	1 (+)	+ (+)	1 (1)	1 (1)	1 (+)

[1]Means are based on 6 sites, except for the 1999 non-chained treatment which is based on 5 sites (Railroad site excluded).
[2]Value on left is mean percent cover for 100 m^2 plots; value in parentheses is mean percent cover for 1 m^2 plots.
[3]Scientific names are given in Table 3.
[4]Means within rows followed by the same letter of the same case were not significantly different at alpha = 0.05 as determined by Tukey's HSD in a mixed-model, first-order autoregressive repeated measures analysis.+ indicates mean values less than 0.5; other values are rounded to the nearest whole number.

by chaining, seeded plants established primarily in washes, soil cracks, and beneath burned juniper or pinyon trees. The soil surfaces beneath these trees were typically blackened, devoid of litter and plants, and probably hydrophobic (Blank et al. 1995). Nevertheless, some seeded plants established in this soil, perhaps because soil movement due to uneven topography or low organic cover enhanced seed burial. The highest measured cover of seeded grasses in a non-chained treatment occurred at the Dog Slopes site, where establishment may have been enhanced by soil movement downslope and by favorable water relations on the mostly northeast-facing slopes. Koniak (1983) reported that establishment of aerially-seeded intermediate wheatgrass following fire on pinyon-juniper sites was greater on north-facing slopes than on other aspects. The experience of the BLM in the region of this study suggests that aerial seeding without chaining can be successful in higher-elevation areas where soil water tends to be greater, specifically above 1,830 m elevation, on sloping topography where seed can be broadcast onto a winter snowpack (BLM personal communication, MacDonald 1999). The relatively high cover of seeded grass observed at the Dog Slopes site suggests that aerial seeding may be successful at elevations below 1,830 m on cooler exposures.

Seed burial can increase the chances of successful plant establishment, but climatic factors ultimately determine the outcome of wildfire rehabilitation and other rangeland revegetation projects (Call and Roundy 1991). Low precipitation was implicated as the primary reason for the limited success of wildfire rehabilitation treatments studied by Ratzlaff and Anderson (1995) in southeastern Idaho. In contrast, precipitation events in west-central Utah following the 1996 fires were initially highly favorable for plant establishment and growth. Several peaks of above-average precipitation occurred in 1997 and 1998 during spring and early summer (Fig. 2), the period of growth for seeded grasses. These were exceptional conditions associated with an El Niño event, and would not be expected during most years in this region.

Results of this study indicate that aerial seeding of agronomic cultivars of introduced grasses (see Table 2) followed by chaining will provide perennial plant cover and soil stability. Chaining is a more efficient means of rehabilitation than drill seeding when a large acreage is involved (BLM 1999b). Agronomic cultivars of introduced grasses are often preferred over native grasses by managers because of their availability, adaptability, responsiveness to standard seeding methods, and utility (Richards et al. 1998, Asay et al. 2001).

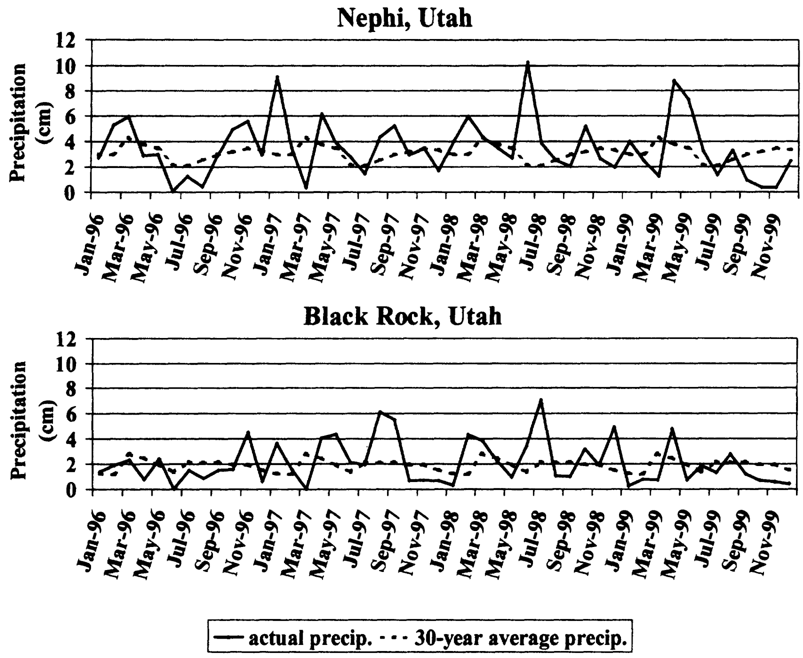

Fig. 2. Monthly precipitation from 1996 to 1999 at 2 weather stations in west-central Utah (NOAA 1996–1999).

Cheatgrass Dynamics

Cheatgrass suppression is a common management goal in consequence of the increased fire risks, decreased resource values, and loss of ecological diversity that arise when cheatgrass becomes dominant (Whisenant 1990, Monsen 1994, Roberts 1999). The ability to compete with cheatgrass is an important requirement for rehabilitation plant materials, given the near-ubiquitous occurrence of cheatgrass in the semiarid zones of the Intermountain West (Monsen 1994).

Although the fires likely reduced the amount of viable cheatgrass seed present at our study sites, especially in subcanopy zones of shrubs and trees, an adequate seed bank and favorable climatic conditions following fires allowed cheatgrass population explosions (Young and Evans 1978, Ott et al. 2001). Cheatgrass benefitted from high precipitation events of autumn 1997 and early spring 1998 (Fig. 2), and above-average temperatures of the intervening winter (NOAA 1997, 1998)

Chaining could have initially inhibited cheatgrass establishment by burying cheatgrass seed too deeply for successful germination or affecting seedling emergence (Wicks 1997). However, a chained surface could subsequently promote cheatgrass invasion because of its rough surface microtopography (Evans and Young 1972). The presence of seeded grasses appears to have been the principal factor that kept cheatgrass cover lower in the chained treatment.

Successful competitiveness against cheatgrass has been demonstrated for commonly seeded plants including 'Hycrest' crested wheatgrass, 'Luna' intermediate wheatgrass, 'Bozoisky' Russian wildrye, and smooth brome (Aguirre and Johnson 1991, Francis and Pyke 1996, Wicks 1997, Whitson and Koch 1998). Nevertheless, at certain sites such as the Railroad site, large amounts of cheatgrass were found in the interspaces among seeded grasses. The extent of cheatgrass invasion may be influenced by the density and composition of seeded grasses, or by other site-specific environmental variables such as elevation, soils, slope, and aspect. In our study, cheatgrass was most abundant on sites at lower elevations in central valley areas, especially the Railroad and Jericho sites. The least cheatgrass occurred on the Dog Slopes site, located on a northeast-facing exposure that also had the highest native perennial grass cover. The native perennial grasses bluebunch wheatgrass and bottlebrush squirreltail can also have a competitive impact on cheatgrass growth and reproduction as mature plants (Harris 1967, Monsen 1994, Stevens 1997). Suppression of cheatgrass invasion following fire has been observed in areas where these grasses or other fire-tolerant native plants were abundant in the pre-burn plant community and readily recovered following fire (West and Hassan 1985, Ratzlaff and Anderson 1995).

Impacts on Native Plants and Diversity

Responses of native species were not as statistically conclusive in our study as were seeded species and cheatgrass, but they offer rough insights concerning native plant performance after aerial seeding and chaining following wildfire. Species with approximately equal frequency and cover in chained and non-chained treatments during the first year of this study are assumed to have been unaffected by chaining and to have been approximately equal in frequency before the fires. Chaining may have directly influenced species that differed in first-year frequency and cover between treatments. Seed burial at depths inhibiting germination or emergence may account for lower frequencies of many annual species in the chained treatment, with the exception of common sunflower, which has large seeds whose germination may have been enhanced by burial.

Chaining reportedly minimally affects post-fire recovery of native perennial grasses and forbs (Monsen, personal communication). This was true for most native perennial species in our study, although frequency and cover of bluebunch wheatgrass and muttongrass were slightly lower in the chained treatment. The potential for uprooting established perennials by chaining in certain soil types, with varying soil water and larger chain size should be investigated further.

Changes in abundance of native species over the 3-year course of the study may have been due to a combination of succession, climatic factors, and competition. High native species diversity in 1997 could be attributed to the presence of surviving components of the pre-burn community, combined with a seed bank of species that respond to burns, e.g., floccose gilia, common sunflower, whitestem blazingstar, coyote tobacco—see Table 3. Annual forbs such as floccose gilia and coyote tobacco are common following fire in the pinyon-juniper zone of the Great Basin, but decline as succession proceeds (Everett and Ward 1984). Successional changes may have been accelerated by the rapid expansion of grasses during favorable climatic conditions in 1998. If this were the case, our results suggest that seeded grasses and cheatgrass had similar competitive impacts, because native species declined in both the areas dominated by seeded grasses and those dominated by cheatgrass. Climatic conditions may have interacted with competition to cause these declines. Established native grasses appeared to withstand competition from seeded grasses and cheatgrass for the duration of this study, although their growth and recruitment would have probably been greater in the absence of such competition (Harris 1967, Reichenberger and Pyke 1990). The long-term outcome of competitive interactions among species was not revealed by our short-term study.

Based on our results we suggest that the influence of seeded plants on native plants may be minimal in the short term, or perhaps no worse than the alternative influence of cheatgrass proliferation. If the reestablishment of native vegetation is desired, the long-term affects of introduced plants are of more concern. Several authors have expressed concern over the competitive, persistent nature of crested wheatgrass, intermediate wheatgrass, and smooth brome on seeded sites (Anderson and Marlette 1986, Lesica and DeLuca 1996, Walker 1999). Much emphasis has recently been placed on using native plant materials for wildfire rehabilitation on public lands of the Intermountain West, for the purpose of maintaining site biodiversity and ecosystem function (Richards et al. 1998, Brown and Amacher 1999, McArthur and Young 1999). We support this ideal while recognizing some yet-unresolved practical limitations, such as the difficulty of establishing native grasses on drier sites (Asay et al. 2001).

Additional Management Implications

A relationship between perennial grass establishment and soil protection was not clearly indicated by this study, because soil cover provided by seeded grasses was low during the first season following the fire, and cheatgrass rapidly covered the soil in areas where seeded grasses were not present. Dense cheatgrass stands offer soil protection (Young and Allen 1997). But because of low cheatgrass cover during drought years (Hosten and West 1994) and repeated soil denudation following burning of cheatgrass stands, soil loss may be high in cheatgrass stands in the long term. Managers should realize that ground cover is not the only factor influencing soil erosion, and that revegetation treatment will not affect erosion rates in the same manner at all sites. Differences in background site erosion potential, which is related to soil characteristics, geomorphology, and climate, may cause some sites to be inherently more erodible than others (Davenport et al. 1998).

Following the 1996 fires, an overriding concern for soil protection and weed suppression, plus the logistical dilemma of rehabilitating a huge burned acreage, led the BLM Fillmore Field Office to rely on standard rehabilitation techniques and plant materials. Rehabilitation was planned even for locations where it might not have been necessary to maximize the probability for soil protection and weed suppression. Consideration of a different set of risks (impact of chaining treatments on archeological sites and on the integrity of wilderness resources and native vegetation) led others to conclude that the application of rehabilitation should be minimized. Ideally, open communication of objectives and concerns in a public participatory process can lead to compromises in public lands management issues, but when fundamental differences are involved, consensus is difficult (SUWA 1994, Moote and McClaran 1997).

Because of issues such as the chaining controversy which followed the 1996 fires, the BLM has recently revised certain aspects of their approach to wildfire rehabilitation. One such revision was the introduction of Normal Fire Rehabilitation Plans, which entail environmental assessments and public participation in advance of potential wildfires (BLM 1999a). Such measures have the potential to streamline the rehabilitation process and reduce controversy in the event of an actual wildfire. Planning for the future is prudent, in view of the likelihood of continued wildfire impacts on public lands of the Intermountain West. Foresight, clear management objectives, public support, appropriate technology, and ecological understanding will contribute to the success of wildfire rehabilitation programs.

The results of this study support chaining as a method to better establish aerially seeded species over the alternative of no seedbed preparation or seed coverage in wildfire rehabilitation plantings. The establishment of seeded species also reduces the incidence of cheatgrass in the post-fire communities.

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