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ABSTRACT

Critical wildlife habitat supporting mule deer, antelope, and sage grouse in high elevation rangeland and sagebrush ecosystems of southwest Wyoming is threatened by an expanding population and energy exploration and development. Our objective was to evaluate native shrub species establishment for restoration after disturbance. In October 2005, on a well-pad disturbance, 16 accessions of 12 native shrub species were drill-seeded in single species plots in a randomized complete block design with four replications. Also, two seed mixtures (Bridger and Shell) of grass, forb, and shrub species were broadcast- or drill-seeded, and one seed mixture (Shell) was hydro-seeded to separate areas outside of the replicated plots. Densities were sampled in September 2007. By 2007, nine of the 16 shrub accessions established in the replicated plots. Atriplex aptera *had the greatest establishment at six plants/m^2 followed by* Atriplex canescens *at four plants/m^2. Establishment of the other seven accessions was similar and ranged from two to 0.4 plants/m^2. Where the Bridger mix was broadcast seeded,* Artemisia tridentata *ssp.* wyomingensis*,* Atriplex aptera*, and* Krascheninnikovia lanata *establishment was estimated at 10,000, 6,770, and 1,120 plants/ha, respectively. Where drill seeded, establishment of the three shrubs was 0, 4,480, and 2,240 plants/ha, respectively. Where the Shell mix was broadcast seeded,* Artemisia tridentata *ssp.* wyomingensis*,* Krascheninnikovia lanata*, and* Atriplex canescens *establishment was estimated at 21,300, 4,500, and 4,500 plants/ha, respectively. Where drill seeded, establishment for the three species was 7,800, 10,000, and 1,100 plants/ha, respectively. Where the Shell mix was hydro-seeded, only* Krascheninnikovia lanata *established at 1,100 plants/ha.*

INTRODUCTION

For over 50 years, the Plant Materials Program of the Natural Resources Conservation Service (NRCS) has been assembling, testing, and releasing shrubby plant materials for conservation use. Since the release *of Lespedeza thunbergii* (Thunberg's Lespedeza) in 1952, the program has released 78 native subshrub and shrub accessions nationally for commercial propagation, and developed techniques for their successful use and management. On western wildlands, disturbance associated with resource extraction poses a conservation problem by threatening soil, water, wildlife, and plant resources. Developing and evaluating plant materials for restoration of native plant communities on these sites has been a NRCS priority.

Shrubs accelerate soil development, enhance plant and animal diversity, increase forage production, and provide faunal cover and wildlife food (Booth 1985). Many species developed by the NRCS are important for restoration of western shrublands and wildlife habitat. *Artemisia ludoviciana* (white sagebrush) released in 1986, is used by small animals including sage grouse, rabbits, chipmunks, ground squirrels and other rodents, as well as antelope, mule deer, elk, mountain sheep and cattle (Stevens and others 2006). *Artemisia tridentata* ssp. *vaseyana* (mountain big sagebrush) released in 1987, provides thermal and security cover for wildlife, nesting cover for species of grouse and other upland birds, and winter forage for many large wildlife ungulates (Tilly and others 2006). Four species of *Atriplex* (saltbush) released from 1979 through 2002, are highly palatable to livestock and big game, provide diversity for reclamation projects, and make excellent screens, hedges, and barriers for erosion control (Ogle and St. John 2005). *Krascheninnikovia lanata* (winterfat) establishes fairly easily on disturbed sites, helps stabilize soils, and is considered good browse and forage for wildlife and livestock (Ogle and others 2003). *Purshia tridentata* (antelope bitterbrush) released in 1984 and 1997; provides erosion control on disturbed lands, is high quality spring and winter browse for wildlife, cover for small animals and birds, and the seeds are a food source for small animals (Dyer and Noller 2007).

Currently, the high demand for energy has resulted in an expansion of oil and gas extraction on the Pinedale Anticline and Jonah Gas Field regions of Sublette County, Wyoming. The high elevation sagebrush ecosystem of the area is important habitat to mule deer, antelope, sage grouse, and other wildlife. Restoration of native plant communities is important for maintaining wildlife habitat (Wood and others 1995) as well as preventing soil erosion (Grantz and others 1998) and noxious weed invasion. Challenges to restoration of native plant species in this ecosystem include short growing season, low and uncertain precipitation, high summer temperatures during drought periods, coarse soils with low water holding capacity, invasive plant species, and domestic and native ungulate herbivory. Loss of soil structure and compaction associated with drill site disturbance may impede restoration under these site conditions.

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Our objective was to evaluate cultivars, varieties, and germplasms of grass, forb, and shrub species for adaptation to the Pinedale Resource Area with emphasis on plant species native to the Rocky Mountain Region that provide forage production, a diverse ecosystem, and habitat for sage grouse, mule deer, antelope and other wildlife species, especially those dependent upon sagebrush communities. An additional objective was to evaluate seeding methods and seeding mixtures for adaptation and desired ecological diversity in the Pinedale Resource Area. In this proceeding, we report the results of native shrub establishment.

METHODS

Site Description

The project area is a 1.5 ha (3.8 ac) well-pad approximately 48 km (30 miles) south of Pinedale, WY (N ½ SW ¼ Section 10, T29N R107W). The nearly level site is within the cool central desertic basins and plateaus major land resource area (MLRA 34A) at an elevation of 2,193 m (7,195 ft). Average annual precipitation is 254 mm (10 inch), mainly in the form of snow. The peak growing season (70 days) is from May to July. The soils are mostly deep and well drained, fine sandy loam to sandy loam and loamy fine sand. Surface layers are 127 mm (5 inch) or more deep with sandy clay loam subsoils. The major soil series include Bluerim-Forelle complex and Bluerim-Cotha complex. The dominant vegetative cover type is classified as sagebrush steppe and the potential natural vegetation is estimated at 70 percent grass and grass-like plants, 10 percent forbs, and 20 percent woody plants. The key grass species are *Hesperostipa comata* (needle and thread), *Elymus lanceolatus* (thickspike wheatgrass), *Achnatherum hymenoides* (Indian ricegrass), and *Pseudoroegneria spicata* (bluebunch wheatgrass). The forbs include *Aster* spp. (aster), *Erigonum* spp. (buckwheat), *Dalea* spp. (clover), *Oenothera* spp. (evening primrose), *Erigeron* spp. (fleabane), and *Artemisia frigida* (fringed sagewort). Shrub cover is dominated by *Artemisia tridentata* (big sagebrush), *Ericameria nauseosa* and *Ericameria teretifolia* (rubber and green rabbitbrush), *Purshia tridentata* antelope bitterbrush, and *Krascheninnikovia lanata* (winterfat). The total annual production (air-dry weight) ranges from 786 kg/ha (700 lb/ac) in unfavorable years up to 1680 kg/ha (1,500 lb/ac) in favorable years.

Procedures

A 1.5 ha square oil/gas well pad was constructed in 2002. Approximately 15 cm (6 inch) of topsoil was stripped and stockpiled for 37 months. During reclamation following development, the topsoil was re-applied to the disturbed area. The soil was then ripped to mitigate heavy equipment compaction and restore infiltration and firmed and smoothed to create a seedbed so no more than a 1/8 inch imprint was left when walking over the site. Weeds were controlled using tillage and glyphosate at 3 kg active ingredient/ha (2 qt product/ac) prior to planting. The entire 1.5 ha site was fenced with 1.8 m (6 ft) tall woven field fence.

In November 2005, 16 accessions of 12 shrub species (table 1) were seeded as monocultures using a four-row Kincaid Precision Cone-seeder in 1.2 by 6 m (4 by 20 ft) plots arranged in a randomized complete block study design with four blocks. The seeding rate was 2.15 million pure live seeds (PLS)/ha (871,000 PLS/ac). Two multi-species mixtures, Bridger and Shell (tables 2 and 3, respectively) were seeded on adjacent 0.17 ha (0.42 ac) plots. The 15-species Bridger mix was 40 percent grass, 33percent forb, and 27percent shrub was drill-seeded with a Truax® drill at a rate of 11.34 kg PLS/ha (10.12 lb PLS/ac) on one plot and broadcast using an ATV-mounted broadcast seeder at 22.68 kg PLS/ha (20.24 lb PLS/ac) on a separate plot. The 10-species Shell mix was 20 percent grass, 40 percent forb, and 40 percent shrub, and was drill-seeded with a Truax® drill at a rate of 5.8 kg PLS/ha (5.18 lb PLS/ac) on one plot and broadcast using an ATV-mounted broadcast seeder at 11.6 kg PLS/ha (10.34 lb PLS/ac) on a separate plot. In addition, one 0.4 ha (1 ac) plot was hydro-seeded with the Shell mixture at 11.6 kg PLS/ha (10.34 lb PLS/ac). The hydro-seeded area was prepared to a smooth slope without roughening to catch seed.

Table 1—The shrub species and their common names, cultivars, and accession numbers seeded on the Pinedale evaluation planting.

Scientific Name	Accession/	Common Name
Artemisia frigida	9087555	fringed sagewort
Artemisia ludoviciana	9087556	prairie sagewort
Artemisia nova	9087557	black sagebrush
Artemisia tridentate ssp. tridentata	9087558	basin big sagebrush
Artemisia tridentata ssp. wyomingensis	9087559	Wyoming big sagebrush
Atriplex aptera		Wytana fourwing saltbush
Atriplex canescens		Snake River Plains fourwing saltbush
Atriplex confertifolia	9087561	shadscale saltbush
Atriplex falcate (A. gardnerii)	9016134	Gardner's saltbush
Atriplex tridentata	9087560	basin saltbush
Grayia spinosa	9087563	spiny hopsage
Krascheninnikovia lanata		Northern Cold Desert winterfat
Krascheninnikovia lanata		Open Range winterfat
Krascheninnikovia lanata		Hatch winterfat
Purshia tridentata		Maybell antelope bitterbrush
Purshia tridentata	9087562	antelope bitterbrush

Sampling and Analysis

The plots were sampled in September 2007. In the replicated mono-species plots, emerged shrubs seeded in the plots were counted within 0.3 m (1 ft) linear sample plots at three randomly chosen locations in each of the middle two rows of the treatment plot for a total of six 0.3 m (1 ft) samples per plot. Plant height was measured from representative plants in each sample plot. Plant vigor and relative stand establishment were visually estimated for the entire plot. Additional comments were noted on items such as the presence of animal and bird life, and grazing or browsing activity. In the species mixture plots, plant density by species was counted in 10 randomly located 0.9 m^2 (9.62 ft^2) sample plots. A relative rating of plant vigor and stand establishment, height, and other comments were also recorded.

Table 2—The species composition and percent of mixture of the Bridger Mixture at the Pinedale evaluation planting.

Scientific Name	Common Name	Percent of Mixture
Elymus trachycaulus	Pryor slender wheatgrass	12.8
Elymus lanceolatus	Critana thickspike wheatgrass	12.8
Pascopyrum smithii	Rosana western wheatgrass	12.8
Poa secunda (*P. sandbergii*)	High Plains Sandberg bluegrass	12.8
Achnatherum hymenoides	Rimrock Indian ricegrass	12.8
Leymus cinereus	Trailhead basin wildrye	7.7
Achillea millefolium var. *occidentalis*	Great Northern western yarrow	5.1
Ratibida columnifera	Stillwater prairie coneflower	5.1
Linum lewisii	Maple Grove prairie flax	5.1
Phacelia hastata	Silverleaf phacelia	5.1
Sphaeralcea coccinea	Scarlet globemallow	2.6
Atriplex aptera	Wytana fourwing saltbush	1.3
Krascheninnikovia lanata	Open Range winterfat	1.3
Artemisia tridentata ssp. *wyomingensis*	Wyoming big sage	1.3
Artemisia frigida	Fringed sage	1.3

Plant density and height data from the replicated plots were averaged for each treatment plot and the average was used in the analysis. Average density, height, vigor and stand estimate data from the replicated plots were analyzed using analysis of variance (Statistix 2003). The model included replication and seeded species. Means were compared using Fisher's protected least significant differences test at the 0.05 level of confidence (Peterson 1985). Means were calculated for the density of shrub species counted in the species mixture plots.

RESULTS AND DISCUSSION

The analysis of variance showed the accessions, cultivars, and shrub species established differently in the replicated plots on the reclaimed well-pad site ($P \leq 0.05$). Two years after seeding, 'Wytana' *Atriplex aptera* density averaged six plants/m^2, which was greatest of all species (table 4). It also was one of the tallest, most vigorous, and had the best stand rating of the species (table 4). Snake River Plains *Atriplex canescens* density averaged four plants/m^2, not statistically different than 'Northern Cold Desert' *Krascheninnikovia lanata* (1.8 plants/m^2), Open Range *K. lanata* (1.4 plants/m^2), or the accession of *Artemisia nova* (black sage, 1.4 plants/m^2). These densities meet the requirements of one shrub/m^2 on 20 percent of the area of revegetated new coal mines in Wyoming (Booth and others 1999). The densities of the later three shrubs were not statistically different than densities of *Artemisia tridentata ssp. tridentata*, 'Hatch' *K. lanata*, *Atriplex falcata*, or *Atriplex tridentata* (0.8, 0.8, 0.4, 0.4 plants/m^2, respectively). While these species densities were lower than other species, their vigor rated as well as species with greater density. *Artemisia frigida*, *Artemisia ludoviciana*, *A. tridentata* ssp. *wyomingensis*, *Atriplex confertifolia*, *Grayia spinosa*, and the two accessions of *Purshia tridentata* were not found in any of the sample plots. Evidence of browse was noted on *K. lanata*. Shrub densities on ten year old reclaimed coal-mined sites ranged from 0.09 to 1.92 plants/m^2 (Booth and others 1999).

Table 3—The species composition and percent of mixture of the Shell mixture at the Pinedale evaluation planting.

Scientific Name	Common Name	Percent of Mixture
Artemisia tridentata ssp. *wyomingensis*	Wyoming big sagebrush	41.50
Poa secunda (P. sandbergii)	Sandberg bluegrass	30.71
Artemisia frigida	Fringed sagewort	7.53
Penstemon rydbergii	Rydberg's penstemon	7.30
Achnatherum hymenoides	Indian ricegrass	4.68
Achillea millefolium	Native yarrow	4.60
Krascheninnikovia lanata	Winterfat – bearded	1.88
Atriplex canescens	Fourwing saltbush	0.86
Sphaeralcea coccinea	Scarlet globemallow	0.50
Lupinus argenteus	Silvery lupine	0.43

Where the Bridger species mix was drill-seeded, Wytana *Atriplex aptera* and Open Range *Krascheninnikovia lanata* densities averaged 4,480 and 2,240 plants/ha, respectively, in the 2007 sample plots. Where broadcast-seeded, *Artemisia tridentata* ssp. *wyomingensis*, Wytana *A. aptera*, and Open Range *K. lanata* densities averaged 10,000, 6,770, and 1,120 plants/ha, respectively. Where the Shell species mixture was drill-seeded, *A. tridentata* ssp. *wyomingensis*, *K. lanata*, and *Atriplex canescens* densities averaged 7,800, 10,000, and 1,100 plants/ha, respectively. Where the Shell species mixture was broadcast-seeded their densities averaged 21,300, 4,500, and 4,500 plants/ha, respectively. Only *K. lanata* established at 1,100 plants/ha where the Shell mix was hydro-seeded.

Table 4—Mean values generated from ANOVA for density, height, vigor, and relative stand establishment of 16 shrubs seeded in replicated plots at the Shell Field Evaluation Planting near Pinedale, Wyoming. Vigor and stand were rated on a scale of 1 to 10 with being the best. Means followed by the same letter are not significantly different determined by LSD ($P < 0.05$) from other means within the column.

Scientific Name	Density Per m^2	Height (cm)	Vigor	Stand
Atriplex aptera	6.2 a	18 ab	4.2 ab	5.5 b
Atriplex canescens	3.7 b	24 a	2.8 b	5.0 b
Krascheninnikovia lanata (Northern Cold Desert)	1.8 bc	12 bc	5.0 ab	9.0 a
Krascheninnikovia lanata (Open Range)	1.4 bc	10 bc	4.5 ab	7.8 a
Artemisia nova	1.4 bc	8 cd	6.3 a	8.8 a
Artemisia tridentate ssp. *tridentata*	0.9 c	17 ab	4.8 ab	8.5 a
Krascheninnikovia lanata (Hatch)	0.9 c	10 bc	5.0 ab	8.0 a
Atriplex falcata (A. gardnerii)	0.4 c	13 bc	4.3 ab	8.0 a
Atriplex tridentata	0.4 c	7 c	6.5 a	9.0 a
Artemisia frigida	0	0	0	0
Artemisia ludoviciana	0	0	0	0
Artemisia tridentate ssp. *wyomingensis*	0	0	0	0
Atriplex confertifolia	0	0	0	0
Grayia spinosa	0	0	0	0
Purshia tridentata	0	0	0	0
Purshia tridentata	0	0	0	0

The seed mixture plots demonstrate either seed mix applied at any of the three seeding methods can meet the post-mining shrub density requirement on coal-mined lands in Wyoming of one shrub/m^2 on 20 percent of the affected area (Booth and others1999). The hydro-seeding application of the Shell mixture resulted in the lowest shrub density and diversity, and lowest overall plant diversity (data not shown) of the five applications. Either drill- or broadcast-seeding the Shell mixture with a greater proportion of shrub seeds than the Bridger mixture resulted in greater than one shrub/m^2 and within the range of densities found in southwest Wyoming (Booth and others 1999). Broadcasting the Bridger mixture also resulted in shrub densities within this range. Broadcast-seeding favored the establishment of *Artemisia tridentata* ssp. *tridentata* regardless of the seed mixture. Newman and Redente (2001) found native plant communities seeded and established on a disturbed sagebrush site in northwestern Colorado remained persistent over 20 years, and inhibited colonization of neighboring species. Although irrigation was not a treatment in this study, initial irrigation increased the long-term production of the native plant community, especially the forbs and shrubs, on the Colorado site (Newman and Redente 2001).

Atriplex canescens may be the most seeded western shrub species on disturbed sites and its successful establishment has been widespread (Booth 1985). It is considered one of the more valuable shrubs for all classes of livestock and wildlife. It may aid the reestablishment of sagebrush by providing favorable microclimates for seedlings and supporting mycorrhizae. As a pioneer species, it is considered to facilitate succession in sagebrush communities. It has been suggested that successful *A. canescens* establishment may exclude other shrubs. However, on a revegetated coal-mined site in eastern Wyoming, seedling Wytana *Atriplex aptera* at densities ≤ 5 seedlings/m^2 were unlikely to deter the development of a sagebrush stand (Booth 2002).

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