COMPARATIVE EVALUATION OF GRASSES, FORBS, AND SEED MIXTURES FROM "LOCAL" VERSUS "NON-LOCAL" ORIGINS AT (STUCKY RIDGE) ANACONDA, MT[1]

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Abstract: The Stucky Ridge test plot is located approximately two miles northeast of Anaconda, Montana. Sparse vegetation includes quaking aspen, Wood's rose, currant species, rubber rabbitbrush, horsebrush, redtop and basin wildrye. In November 2002, 22 tons/acre lime kiln dust was disced to a 12" depth. Prior to spring seeding, 500 bulk-pounds of fertilizer were applied/incorporated to a 6" depth. Thirty-six grass, two subshrub accessions, and four seed mixtures were arranged in a Randomized Complete Block with four replications. Plots were drill-seeded in May 2003 at 50 Pure Live Seeds per linear row foot. Soil sampling for arsenic and heavy metals occurred after planting. A significant amount of new grass seedling emergence was detected during the June 2004 evaluation, particularly for Indian ricegrass, western wheatgrass, Nevada bluegrass, and basin wildrye. Following the 2004, 2005, and 2006 evaluations for cover and vigor rating, each plot was sampled for biomass production. Tissue analyses indicated heavy metal concentrations were generally within limits for livestock and wildlife use. In single-species plots, 'local source' plants exhibiting superior performance included Copperhead and 9081621 slender wheatgrass, Opportunity Nevada bluegrass, 9081968 western wheatgrass, 9081624 and Washoe Germplasm basin wildrye, 9081628 Indian ricegrass, 9081636 bluebunch wheatgrass and 9081635 Canbyi bluegrass. In 2003, Open Range Germplasm winterfat was the only broad-leaved entry demonstrating significant emergence. In 2007, the only broad-leaved plants surviving were Open Range winterfat and 9081632 silverleaf phacelia. Old Works fuzzytongue penstemon and silverleaf phacelia were only detected in alternating years. In the Seed Mixture Trials, the 'Experimental' mixes containing native 'local source' were far superior to the 'Developed' mixes consisting of native 'nonlocal source' (Upland Mix) and introduced cultivars (Waste Management Areas). However, it was estimated the majority of plants in the Experimental mixtures were Copperhead slender wheatgrass, the best overall performer on the test site.

Additional key words: lime kiln dust, arsenic, heavy metals, livestock, wildlife.

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Introduction

Currently the commercial varieties (non-local origin) being utilized at the Anaconda Smelter National Priorities List (NPL) site include 'Pryor' slender wheatgrass, 'Sherman' big bluegrass, 'Sodar' streambank wheatgrass, 'Trailhead' basin wildrye, 'Secar' and 'Goldar' bluebunch wheatgrass, 'Rosana' western wheatgrass, 'Critana' thickspike wheatgrass and 'Appar' Lewis flax. Most of these varieties were developed for coal mineland reclamation in the saline, high pH soils found in eastern Montana and Wyoming. In this report, accessions originating from metalliferous soils are referred to as "local", whereas accessions originating from undisturbed soils are referred to as "non-local". The study's objective is to identify and develop metal-tolerant plant varieties adapted to the edaphic conditions found at the Anaconda Smelter NPL site in western Montana (local origin) and other mine-affected areas with similar climatic and soil characteristics. The investigation is based on the premise germplasm, originating from low pH and metalliferous soils, will exhibit significantly better establishment, cover, and biomass production than commercial germplasm when grown in lime-amended metalliferous soils at the Anaconda Smelter NPL Site.

Methods and Materials

Study Site

Located on Stucky Ridge, the study is approximately1.2 kilometers northeast of Anaconda, Montana, in Deer Lodge County. The legal description and geographic position of the study site are the SW 1/4 of the SW 1/4 of Section 30, Range 11 West, Township 5 North and North 46°09'09"/ West 112°54'30". The study plot occupies 0.6 hectares in subpolygon OWSR-013.09, which is part of the Stucky Ridge Remedial Design Unit #1 within the Anaconda Regional Water, Waste, and Soils Operable Unit.

Remedial Design Unit (RDU) #1 encompasses 97.9 hectares of the ~5261 hectares of upland terrestrial vegetation contaminated by emission fallout from the Washoe, as well as the Upper and Lower Works smelters. Concerns identified in the Stucky Ridge RDU include elevated arsenic concentrations in surface soils, barren or sparsely vegetated areas due to low pH and elevated contaminant concentrations, and steep slopes with high erosion potentials (ARCO 2002, May) (Table 1). Current and historic use of the area primarily consists of agricultural grazing, recreation, and open space/wildlife habitat.

Table 1. Pre-tillage soils data in the proximity of the plot site (ARCO 2002, May).

Soil Sample	Depth	As	Cu	Zn	Sat. Paste
	cm	*mg/kg*	*mg/kg*	*mg/kg*	*s.u.*
94S-SR-71	0-5	-----	-----	-----	4.70
94S-SR-71	5-20	-----	-----	-----	4.90
94S-SR-73	0-5	-----	-----	-----	4.30
94S-SR-73	5-20	-----	-----	-----	4.60
99-098A	0-5	495.0	1660.0	419.0	-----
99-098B	5-15	163.0	1320.0	276.0	-----
99-098C	0-15	-----	-----	-----	4.20
99-098D	15-30	-----	-----	-----	7.60
99-098E	12-46	-----	-----	-----	7.80
99-099A	0-5	489.0	1370.0	303.0	-----
99-099B	5-15	95.8	1020.0	245.0	-----
99-099C	0-15	-----	-----	-----	4.00
99-099D	15-30	-----	-----	-----	7.30
99-099E	12-46	-----	-----	-----	7.70
99-123A	0-5	656.0	1530.0	425.0	-----
99-123B	5-15	167.0	1530.0	332.0	-----
99-123C	0-15	-----	-----	-----	4.40
99-123D	15-30	-----	-----	-----	4.80
99-123E	30-46	-----	-----	-----	6.30
99-163A	0-5	537.0	2180.0	493.0	-----
99-163B	5-15	256.0	1430.0	365.0	-----
99-163C	0-15	-----	-----	-----	4.00
99-163D	15-30	-----	-----	-----	6.20

The plot site is situated on a stream terrace above Lost Creek at an elevation of 1618 meters and covers most of the relatively flat ground on the east end of Stucky Ridge. Vegetation, although sparse, includes scattered groves of quaking aspen, shrublands dominated by Wood's rose, currant species, rubber rabbitbrush, and horsebrush; and grasslands dominated by redtop and basin wildrye. Annual precipitation at the site ranges from 25.4 to 35.6 centimeters with most of the precipitation occurring in the spring. The parent material is alluvium and the soil has a gravelly loam texture, which is well drained. Slope at the plot site averages approximately 5 to 10 percent.

Soil Treatment

The study plot site was ameliorated along with the rest of treatment area (OWSR-013.09) following the remedial actions specified in the Remedial Action Work Plan/Final Design Report

(ARCO 2002, May). A remedy identified for the treatment area was soil tilling to 30 centimeters with the addition of a neutralizing amendment to ameliorate the low pH soil conditions. Remediation of the area was performed by Jordan Contracting, Inc. and their subcontractors starting in the fall of 2002. According to the work report from Jordan Contracting, Inc. (Bahr 2003, February 18) prior to tillage, many of the erosion rills and gullies were graded using a D8 Dozer and a CAT 330 excavator. The entire treatment area was pre-tilled by Western Reclamation, Inc. with a Rhome™ disc to approximately 30 centimeters in mid-September. Lime kiln dust, procured from Continental Lime, Inc., was then applied at a rate of ~55 tonnes/hectare to neutralize the soil. Four additional passes were made with the Rhome™ disc to a depth of 30 centimeters to incorporate the lime. Lime incorporation was completed on November 14, 2002.

In the spring of 2003, fertilizer (12% N, 16% P_2O_5, 30% K_2O) was applied at a rate of 494 bulk kilograms per hectare and incorporated to 15 centimeters using a chisel plow. The tillage area was drill seeded in early May 2003 at a rate of 27 kgs/hectare with "Revegetation Mix #1." Soil characteristics of pre-tillage soil data points closest to the study site (northwest portion of treatment area [OWSR-013.09] as stated in the Remedial Action Work Plan/Final Design Report [ARCO 2002, May] are listed in Table 2.

Post-Treatment Soil Sampling Methods

Soil sampling of the grass, forb/subshrub, and seed mixture trials was completed on June 24, 2003, after planting. The soil samples were analyzed for pH (1:1 saturated paste), and total As, Cd, Cu, Pb, and Zn by Energy Laboratories, Inc. in Billings, Montana. At the grass trial eight randomly selected treatment blocks in each replication were subsampled. The eight (0 to 15 cm) composite subsamples collected from a replication were combined and mixed to form one representative sample. Duplicate soil samples were taken in replication 1 and alternate soil samples were taken in replication 3. In the forb/subshrub trial, four (0 to 15 cm) subsamples were taken per replication to form one representative sample. Duplicate subsamples were taken in replications 1 and 3. In the mixture trial, two (0 to 15 cm) subsamples were taken per replication to form one representative sample. Duplicate subsamples were taken in replication 1 and alternate subsamples were taken in replication 3.

Table 2. Post-planting grass, forb/subshrub, and seed mixture trial (0 to 15 centimeters). Composite soil sample analysis from Stucky Ridge Comparative Evaluation Planting.

Sample Id.	Sample description.	pH	As	Cd	Cu	Pb	Zn
		s.u.	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
GR1	Grass Trial, Rep 1	8.2	120	1	797	35	174
GR2	Grass Trial, Rep 2	8.1	117	1	906	34	177
GR3	Grass Trial, Rep 3	7.9	132	1	833	43	195
GR4	Grass Trial, Rep 4	8.0	212	2	985	61	228
GDR1	Grass Trial, Rep 1, Duplicate	7.7	121	1	703	39	153
GDR3	Grass Trial, Rep 3, Alternate	7.7	178	1	845	57	201
FR1	Forb Trial, Rep 1	8.0	115	1	774	38	185
FR2	Forb Trial, Rep 2	7.2	127	2	888	45	182
FR3	Forb Trial, Rep 3	7.7	153	2	1010	45	220
FR4	Forb Trial, Rep 4	7.6	127	2	1080	40	210
FD1	Forb Trial, Rep 1, Duplicate	8.0	91	ND†	681	31	170
FD3	Forb Trial, Rep 3, Duplicate	7.9	106	1	828	33	171
MR1	Seed Mix. Trial, Rep 1	8.0	39	1	721	6	143
MR2	Seed Mix. Trial, Rep 2	7.5	367	2	909	97	226
MR3	Seed Mix. Trial, Rep 3	7.7	39	ND	706	12	161
MR4	Seed Mix. Trial, Rep 4	7.8	257	2	857	91	209
MDR1	Seed Mix. Trial, Rep 1,	7.4	130	1	925	35	165
MDR3	Seed Mix. Trial, Rep 3,	8.1	29	ND	525	9	153

† ND: Not detected at the reporting limit.

The As and metal concentrations of the post-planting soil samples were generally moderate with the exception of Cu. Copper concentrations within the three trials averaged 832 mg/kg and ranged from 525 mg/kg to 1080 mg/kg. The average Cu concentrations in the grass, forb/subshrub, and seed mixture trials were 845 mg/kg, 877 mg/kg, and 774 mg/kg, respectively. Post-planting soil sample pHs were all above neutral, averaging 7.8 and ranging from 7.2 to 8.2.

Planting Design

The study is arranged as three separate trials (grass, forb/subshrub, and seed mixture) each in a Randomized Complete Block Design replicated four times. The grass, forb/subshrub, and seed mixture trials are 0.39 hectare, 0.18 hectare, and 0.06 hectare, respectively, with a total plot size of 0.63 hectare. Between each replication, as well as between trials, a 2.4 meter strip of *Elymus*

trachycaulus 'Pryor' was planted to minimize edge effect. The seed bed was prepared by DATC Project personnel on April 22, 2003, using a 1.5 meter box scraper to level the soil. Rocks, greater than 15 centimeters in diameter, within the plot boundary were hand-picked. After rock removal, another pass was made with the box scraper and spike-tooth harrow to till out tractor tire compressions.

On May 13, 2003, the seed treatments were planted using a 4-row Kincaid™ cone drill with 18 centimeter row spacing and a 1.2 centimeter planting depth. The seeding rate for the grass and forb/subshrub trials was 50 Pure Live Seeds (PLS) per 30.5 centimeters of row. The seeding rate for the seed mixture trial was based on a total seeding rate of 538 PLS/m^2. Each component of the mix was calculated as a percentage of the m^2 rate.

The seed mixtures were formulated for two distinct applications on an upland area and a mine spoils waste area. An "Upland" blend was designed for sloping areas with generally low water infiltration and to provide wildlife habitat. The "Waste Management Area" (WMA) blend was designed to provide a vegetative cover for areas in which remedial options appear to be limited and their use for containment of large volumes of waste appears logical (EPA, 1995a). "Developed" seed mixtures are the seed formulations, utilizing commercially available cultivars, currently specified for use in the Remedial Action Work Plan/Final Design Report 2002. The seed mixture previously referred to as Revegetation Mix #1, planted in the surrounding treatment area, is synonymous with the "Upland Developed" seed mixture. "Experimental" seed mixtures are local ecotypes of the same species from mine-impacted lands.

Each treatment block is 2.4 meters (eight rows) by 7.6 meters. In the grass and forb/subshrub trials, each treatment block was planted with a single accession. Two exceptions exist due to seed quantity restraints. In all replications of the grass trial, *Pascopyrum smithii* 9081968 was drilled in only six rows with *Elymus trachycaulus* 'Pryor' drilled into the remaining two rows. In all replications of the forb/subshrub trial, *Eriogonum ovalifolium* 9082098 was drilled into only four rows with *Elymus trachycaulus* 'Pryor' drilled into the remaining four rows.

As mentioned above, *Elymus trachycaulus* 'Pryor' was drilled in the border strips and also broadcast in the unplanted area south of the forb/subshrub trial. Wooden stakes, spray painted orange and marked with an identification number, were installed in the northeast corner of each treatment block. Lastly, a single-strand, smooth wire fence was installed around the perimeter of the plot to designate plot boundaries and restrict vehicular trespass. In mid-July and again in

mid-September, volunteer Canadian thistle was spot sprayed initially with a 3% solution of 2,4-D Amine and subsequently with a 3% solution of Stinger™ (clopyralid) applied with a backpack sprayer.

Seeded Species

The species entries consist of 36 grass accessions representing nine grass genera, 14 forb accessions representing five forb genera, two subshrub accessions representing one subshrub species, and four seed mixtures representing two seed mixture formulations (Tables 3-8). The 15 total genera tested were selected for inclusion in the study based on results from previous Development of Acid/Heavy Metal-Tolerant Cultivars (DATC) Project (currently DATR – Development of Acid/Heavy Metal Releases) studies such as the Initial Evaluation Planting study (Marty 2000, July) and the Greenhouse Comparative Evaluation Planting study (Marty 2001, October).

Each genus tested includes at least one accession originating from metalliferous soil sites in the proximity of the Anaconda Smelter NPL Site, except in one case. Neither of the two *Krascheninnikovia lanata* accessions originated from metalliferous soils.

Table 3. Forb and subshrub treatments included in the forb/subshrub trial at the Stucky Ridge Uplands Comparative Evaluation Planting.

Species Id. #	Genus & Species	Accession/Variety	Origin
1	*Eriogonum ovalifolium*	9082098	Deer Lodge County, MT
2	*Eriogonum umbellatum*	9082271	Utah
3	*Eriogonum umbellatum*	9082273	Idaho
4	*Krascheninnikovia lantana*	Northern Cold Desert Germplasm	Composite from UT & ID
5	*Krascheninnikovia lantana*	Open Range Germplasm	Composite from MT & WY
6	*Penstemon eriantherus*	Old Works Germplasm	Deer Lodge County, MT
7	*Penstemon eatonii*	Richfield Selected	Sevier County, UT
8	*Penstemon strictus*	'Bandera' 477980	Torrance County, NM
9	*Penstemon venustus*	Clearwater Selected	Clearwater River area, ID
10	*Phacelia hastata*	9081632	Deer Lodge County, MT
11	*Phacelia hastata*	9082275	California
12	*Potentilla gracilis*	9081679	California
13	*Potentilla hippiana*	9076274	Deer Lodge County, MT
14	*Symphyotrichum chilense*	9078675	Deer Lodge County, MT
15	*Symphyotrichum chilense*	9081678	Colorado
16	*Symphyotrichum chilense*	9082274	Unknown

Table 4. Grass treatments included in the grass trial at the Stucky Ridge Uplands Comparative Evaluation Planting.

Species Id. #	Genus & Species	Accession/Variety	Origin
1	*Achnatherum hymenoides*	9081628	Deer Lodge County, MT
2	*Achnatherum hymenoides*	9081629	Deer Lodge County, MT
3	*Achnatherum hymenoides*	'Rimrock'	Yellowstone County, MT
4	*Achnatherum hymenoides*	'Nezpar'	White Bird, ID
5	*Agrostis gigantea*	9076276	Deer Lodge County, MT
6	*Agrostis gigantea*	9081619	Deer Lodge County, MT
7	*Agrostis gigantea*	9076266	Deer Lodge County, MT
8	*Agrostis gigantea*	'Streaker'	Illinois
9	*Deschampsia caespitosa*	9076290	Silver Bow County, MT
10	*Deschampsia caespitosa*	9082620	California
11	*Deschampsia caespitosa*	'Nortran'	Alaska
12	*Elymus trachycaulus*	Copperhead	Deer Lodge County, MT
13	*Elymus trachycaulus*	9081621	Deer Lodge County, MT
14	*Elymus trachycaulus*	'Pryor'	Carbon County, MT
15	*Elymus trachycaulus*	'Revenue'	Saskatchewan, Canada
16	*Elymus trachycaulus*	'San Luis'	Rio Grande County, CO
17	*Leymus cinereus*	9081624	Deer Lodge County, MT
18	*Leymus cinereus*	9081625	Deer Lodge County, MT
19	*Leymus cinereus*	Washoe Germplasm	Deer Lodge County, MT
20	*Leymus cinereus*	'Magnar'	Saskatchewan, Canada
21	*Leymus cinereus*	'Trailhead'	Musselshell County, MT
22	*Pascopyrum smithii*	9081968[†]	Deer Lodge County, MT
23	*Pascopyrum smithii*	'Rodan'	Morton County, ND
24	*Pascopyrum smithii*	'Rosana'	Rosebud County, MT
25	*Poa alpina*	9016273	Gallatin County, MT
26	*Poa alpina*	01-13-1	British Columbia, Canada
27	*Poa alpina*	'Gruening'	France/Switzerland
28	*Poa alpina*	1858	Unknown
29	*Poa secunda* (*nevadensis*)	Opportunity	Deer Lodge County, MT
30	*Poa secunda* (*ampla*)	'Sherman'	Sherman County, OR
31	*Poa secunda* (*canbyi*)	'Canbar'	Columbia County, WA
32	*Poa secunda*	9081635	Deer Lodge County, MT
33	*Poa secunda*	9081322	Lewis & Clark County, MT
34	*Pseudoroegneria spicata*	9081636	Deer Lodge County, MT
35	*Pseudoroegneria spicata*	'Goldar'	Asotin County, WA
36	*Elymus wawawaiensis*	'Secar'	Washington

Table 5. Upland Areas - Experimental Seed Mix Formulation.

Species Id. #	Genus & Species	Accession/Variety	Origin	Seed Mixture Percentage
1	GRASSES:			
	Achnatherum hymenoides	9081629	Deer Lodge Co., MT	15.0
	Elymus trachycaulus	Copperhead	Deer Lodge Co., MT	15.0
	Leymus cinereus	Washoe Germ.	Deer Lodge Co., MT	15.0
	Pascopyrum smithii	9081968	Deer Lodge Co., MT	5.0
	Poa alpina	90816273	Gallatin County, MT	10.0
	Poa secunda (*nevadensis*)	Opportunity	Deer Lodge Co., MT	15.0
	Pseudoroegneria spicata	9081636	Deer Lodge Co., MT	15.0
	FORBS:			
	Aster chilensis	9078675	Deer Lodge Co., MT	2.5
	Penstemon eriantherus	Old Works Germ.	Deer Lodge Co., MT	5.0
	Potentilla hippiana	9076274	Silverbow County, MT	2.5

Table 6. Upland Areas - Developed Seed Mix Formulation.

Species Id. #	Genus & Species	Accession/Variety	Origin	Seed Mixture Percentage
2	GRASSES:			
	Achnatherum hymenoides	'Nezpar'	White Bird, ID	5.0
	Elymus lanceolatus	'Critana'	Hill County, MT	15.0
	Elymus trachycaulus	'Revenue'	Saskatchewan, Canada	15.0
	Festuca ovina	'Covar'	Central Turkey	10.0
	Leymus cinereus	'Magnar'	Saskatchewan, Canada	15.0
	Pascopyrum smithii	'Rosana'	Rosebud County, MT	10.0
	Poa secunda (*ampla*)	'Sherman'	Sherman County, OR	14.5
	Pseudoroegneria spicata	'Goldar'	Asotin County, WA	10.0
	FORBS:			
	Achillea lanulosa	Great Northern	Flathead County, MT	2.5
	Artemisia frigida	9082258	Unknown	0.5
	Linum lewisii	'Appar'	Custer County, SD	2.5

Table 7. Waste Management Areas - Experimental Seed Mix Formulation

Species Id. #	Genus & Species	Accession/Variety	Origin	Seed Mixture Percentage
3	GRASSES:			
	Agrostis gigantea	9076276	Deer Lodge Co., MT	15
	Deschampsia caespitosa	9076290	Silverbow County, MT	10
	Elymus trachycaulus	Copperhead	Deer Lodge Co., MT	15
	Leymus cinereus	Washoe Germ.	Deer Lodge Co., MT	15
	Pascopyrum smithii	9081968	Deer Lodge Co., MT	5
	Poa secunda (*nevadensis*)	Opportunity	Deer Lodge Co., MT	10
	Stipa comata	9078314	Deer Lodge Co, MT	10
	FORBS:			
	Aster chilensis	9078675	Deer Lodge Co., MT	10

Table 8. Waste Management Areas - Developed Seed Mix Formulation.

Species Id. #	Genus & Species	Accession/Variety	Origin	Seed Mixture Percentage
4	GRASSES:			
	Agropyrum intermedium	'Greenar'	Former USSR	10
	Bromus inermis	'Manchar'	Manchuria, China	15
	Elymus lanceolatus	'Critana'	Hill County, MT	10
	Elymus trachycaulus	'Revenue'	Saskatchewan, Canada	15
	Leymus cinereus	'Magnar'	Saskatchewan, Canada	15
	Poa secunda (*ampla*)	'Sherman'	Sherman County, OR	10
	Stipa viridula	9082255	Washington	10
	FORBS:			
	Medicago sativa	'Ladak'	Kashmir, India	15

Sampling Methods

Seedling density was the growth response variable used to assess performance during the first growing season (2003). Measurements were taken using a 30 x 50 cm quadrat frame randomly placed at five sample locations within each (2.4 x 7.6 meter) treatment block. The quadrat was situated with its long axis perpendicular to the seeded rows so that each sampling measurement included two rows. Seedlings rooted within the quadrat frame were counted. Seeded seedlings, as well as non-seeded seedlings, were counted and recorded separately.

Photographs of each treatment block were taken during sampling events. Density data was collected on June 24, 2003, to assess emergence and initial establishment and on August 25, 2003, to assess subsequent establishment and/or die off.

Data was collected on June 30/July 1 and again on September 22-23, 2004, on August 29-30, 2005, and on August 28-29, 2006. During the early summer sampling, four randomly located frames (30 x 50 cm) were utilized, from which average plant height was measured, percentage stand cover was estimated, and ocular estimates of plant vigor were made. Random samples were located along rows 2-3 and 6-7 to avoid edge-effect error. In the fall the same random frame locations were used to estimate percentage stand cover, plant vigor, plant height (2005) and sample biomass production. If combined biomass samples from all four replications did not yield at least 10 grams of material, additional clipping was done so there would be enough biomass for tissue analysis. All biomass samples were oven dried at 60^0C (140^0F) for 24 hours, weighed, and later cut into small pieces and packaged in plastic zip-lock bags for delivery to Energy Laboratories, Inc. for tissue analysis.

Results and Discussion

Grass Trial (2003)

The grand mean of seedling density data collected on June 24, 2003, in the grass trial was 58.1 seedlings/m^2 and ranged from 3.7 to 161.1 seedlings/m^2 (Table 9). Three accessions of *Elymus trachycaulus* ('Pryor', Copperhead, and 'San Luis') had the greatest seedling densities at 161.1, 151.7, and 146.7, respectively. These results are not surprising as *Elymus trachycaulus* is recognized for excellent seedling vigor and quick establishment and growth on a variety of soil types. Density data collected two months later on August 25, 2003, indicated these three *E. trachycaulus* accessions had significantly greater densities than 86% of the accessions tested. The locally collected *E. trachycaulus* Copperhead, however, did not perform significantly better than 'Pryor' or 'San Luis'.

Pascopyrum smithii ('Rosana' and 9081968) had 143.3 and 136.9 seedlings/m^2, respectively, on June 24 (Table 9). *P. smithii* is an aggressively rhizomatous, long-lived grass known to be adapted to a wide range of soil types from acidic to basic. Seedling density data collected again on August 25 indicated the above *P. smithii* accessions, also had significantly greater densities than 86% of the accessions tested including *P. smithii* 'Rodan'.

Table 9. Density (seedlings per meter squared) sampled on June 24 and August 25, 2003, at the Stucky Ridge Comparative Evaluation Planting grass trial.

Genus & Species	Accession	Species	June 24	August 25
		Id.	*Density/m^2*	
Elymus trachycaulus	'Pryor'	14	161.1 A*	155.8 A*
Elymus trachycaulus	Copperhead	12	151.7 AB	144.7 A
Elymus trachycaulus	'San Luis'	16	146.7 AB	130.6 A
Pascopyrum smithii	'Rosana'	24	143.3 AB	129.2 A
Pascopyrum smithii	9081968	22	136.9 AB	124.8 A
Pseudoroegneria spicata	9081636	34	126.5 BC	90.2 B
Leymus cinereus	9081624	17	121.1 BC	84.1 BC
Elymus wawawaiensis	'Secar'	36	101.9 CD	78.4 BC
Elymus trachycaulus	9081621	13	100.5 CD	77.1 BC
Pseudoroegneria spicata	'Goldar'	35	97.9 CDE	70.6 BC
Achnatherum hymenoides	'Nezpar'	4	96.2 CDEF	70.3 BC
Elymus trachycaulus	'Revenue'	15	94.2 CDEFG	65.6 BC
Poa secunda	9081633	29	76.8 DEFG	61.9 BCD
Leymus cinereus	'Magnar'	20	66.0 EFGH	55.5 CDE
Leymus cinereus	'Trailhead'	21	62.5 FGH	52.9 CDE
Pascopyrum smithii	'Rodan'	23	60.9 GH	32.3 DEF
Leymus cinereus	9081625	18	41.3 HI	26.3 EF
Leymus cinereus	Washoe Germplasm	19	39.4 HIJ	25.2 EF
Poa secunda	'Sherman'	30	33.7 HIJ	24.5 EF
Agrostis gigantea	9081619	6	25.6 IJ	23.3 EF
Poa alpine	9016273	25	25.2 IJ	10.8 F
Poa species	9081635	32	20.2 IJ	13.5 F
Agrostis gigantea	9076276	5	18.8 IJ	11.1 F
Poa alpine	9082266	28	18.5 IJ	10.4 F
Poa species	9081322	33	14.1 IJ	9.8 F
Achnatherum hymenoides	'Rimrock'	3	13.8 IJ	9.8 F
Deschampsia cespitosa	9076290	9	13.8 IJ	9.8 F
Poa secunda	'Canbar'	31	13.1 IJ	9.5 F
Deschampsia cespitosa	'Nortran'	11	10.8 IJ	7.8 F
Agrostis gigantea	9076266	7	8.7 IJ	6.4 F
Achnatherum hymenoides	9081629	2	8.4 IJ	5.7 F
Agrostis gigantea	'Streaker'	8	8.1 IJ	5.1 F
Poa alpine	9082259	26	7.1 IJ	4.7 F
Achnatherum hymenoides	9081628	1	6.4 IJ	4.1 F
Deschampsia cespitosa	9082260	10	6.0 IJ	3.7 F
Poa alpine	'Gruening'	27	3.7 J	3.3 F

*Means followed by the same letter are not significantly different at the 0.05 significance level using the Duncan's Multiple Range Test.

Seedling density data from the June evaluation indicated *Leymus cinereus* 9081624 had significantly greater density (121.1 seedlings/m^2) than 80.5% of the accessions including the four other *Leymus cinereus* accessions (Table 9). However, by the August evaluation *L. cinereus*

9081624 was not significantly better than *L. cinereus* 'Trailhead' (Table 9). The accession's success is somewhat unexpected due to the species' poor to fair seedling vigor and slow seedling establishment. The species has been reported to be tolerant of elevated arsenic and heavy metal concentrations (Munshower 1998, September).

Pseudoroegneria spicata accessions ('Goldar' and 9081636) also performed in the top third of the field in June and August (Table 9). In August, both accessions mentioned above had significantly better seedling densities than >50% of the accessions. The local accession *P. spicata* 9081636 did not perform significantly better than *P. spicata* 'Goldar'. *P. spicata* is reported to have fair seedling vigor and establishment with tolerances to acidic to slightly alkaline soils.

The grand mean for the August 25, 2003, evaluation is 46.3 seedlings/m^2 and ranged from 3.3 to 155.8 seedlings/m^2 (Table 9), indicating seedling density declined by 11.8 seedlings/m^2 or 20.4% between the June and August evaluations.

Grass Trials (2004)

Based on the number of new seedlings found in 2004, there were many seeds that did not germinate during the 2003 growing season. The most notable species were *Achnatherum hymenoides* (Indian ricegrass), *Leymus cinereus* (basin wildrye), and *Pascopyrum smithii* (western wheatgrass). Indian ricegrass has a hard seed coat and should normally be dormant-seeded in the fall, but the basin wildrye and western wheatgrass may have delayed germination because of the combination of a relatively late spring planting date and subsequent hot, dry weather. The increase in new seedlings could be expressed in relatively higher percentage stands, but was not revealed in the biomass production, as seedlings were still quite small at the time of the late summer biomass sampling.

At the early fall sampling (9/22/04), the top accession, by a significant amount, was Copperhead slender wheatgrass (*Elymus trachycaulus*) with a 61.3% stand, 54.4 cm average height, and a 2.1 vigor rating. Other 'local source' accessions exhibiting good survival, stand, and vigor included Opportunity Nevada bluegrass (*Poa secunda*), 9081621 slender wheatgrass (*Elymus trachycaulus*), 9081968 western wheatgrass (*Pascopyrum smithii*), 9081624 basin wildrye (*Leymus cinereus*), 9081628 Indian ricegrass (*Achnatherum hymenoides*), 9081635 Canby bluegrass (*Poa secunda)*, and 9081636 bluebunch wheatgrass (*Pseudoroegneria spicata*) (see Tables 10, 11, and 12).

Of the 'local source' accessions, Opportunity Nevada bluegrass, 9081621 slender wheatgrass, 9081968 western wheatgrass, 9081635 Canby bluegrass, 9081624 basin wildrye, and 9081636 bluebunch wheatgrass all show promise and are among those being increased at the Bridger PMC for potential release to the commercial seed industry. Fall biomass production was relatively low, with only Copperhead slender wheatgrass producing more than 706 kg/ha (2,083 kg/ha) (Table 13). Some of the low production can be attributed to the number of new seedlings emerging in 2004. Also two-year-old plants were often spindly because of the harsh edaphic conditions.

Grass Trials (2005)

Grass plots were evaluated and sampled on August 30, 2005. Although there had been some mortality, the top performers of 2003/2004 continue to exhibit their ability to withstand the harsh edaphic conditions of the site. Slender wheatgrass (Copperhead) is the top performer with an average stand of 75% (Table 10), average plant height of 87.5 cm (Table 11), and average biomass production of 8,211 kg/ha (Table 13). Other superior accessions include Opportunity Nevada bluegrass (stand cover-34.1%, biomass-2,189 kg/ha), 9081621 slender wheatgrass (stand cover-25.9%, biomass-2,506 kg/ha), 9081635 bluegrass (stand cover-13.8%, biomass-906 kg/ha), 9081968 western wheatgrass (stand cover-22.2%, biomass-578 kg/ha), and 9081624 basin wildrye (stand cover-21.6%, biomass-1,844 kg/ha). Released cultivars, Secar Snake River wheatgrass, Pryor slender wheatgrass, San Luis slender wheatgrass, Rosana western wheatgrass, and Trailhead basin wildrye were among the top performers, but in most cases, performances were slightly less than their indigenous counterparts.

Grass Trials (2006)

The grass plots were evaluated and sampled on August 28 and 29, 2006. There has been some change in the order of performance, but the top performers from 2003-2005 are still in the top 10. Slender wheatgrass (Copperhead) is still the top overall performer with an average stand cover of 78.1% (Table 10), average plant height of 78.6 cm (Table 11), and average biomass production of 4,894.4 kg/ha (Table 13). Other top performers include Opportunity Nevada bluegrass, 9081621 slender wheatgrass, 9081635 Canbyi bluegrass, and 9081624 basin wildrye. Western wheatgrass 9081968 dropped from a standing of number 7 in 2005 to number 15 in 2006. The released cultivars, Secar Snake River wheatgrass, Pryor slender wheatgrass, San Luis

slender wheatgrass, Rosana western wheatgrass, and Trailhead basin wildrye were still among the top performers, but their overall performance had not improved by any significance.

Grass Trials (2007)

The grass plots were evaluated and sampled on August 21 and 22, 2007. Six of the top 10 performers were still in the top 10 ranking. Copperhead slender wheatgrass outperformed all other slender wheatgrasses and was again the overall top performer. Opportunity Nevada bluegrass had the greatest stand cover average with 39.7% (Table 10). It leads all bluegrasses with an average plant height of 62.6 cm (Table 22) and is ranked twelfth overall when compared to all grass species (Table 11). Opportunity Nevada bluegrass is ranked sixth in biomass production with an average of 1261.11 kg/ha (Table 13). Other top performers include Copperhead slender wheatgrass, 9081624 basin wildrye, 9081635 Canbyi bluegrass, and 9081621 slender wheatgrass. Released cultivars, such as Secar Snake River wheatgrass, Pryor slender wheatgrass, San Luis slender wheatgrass, and Trailhead basin wildrye were still among the top performers with no significant differences, except for Trailhead, which moved to the top five in all comparisons. Unfavorable soil and weather conditions continued to impact many of the grasses. All of the western wheatgrasses dropped to the lower half of all grasses in performance and the tufted hairgrasses (Nortran, 9076290, and 13970176) and Gruening alpine bluegrass died out in 2007.

Table 10. Percentage stand cover of grass trials on Stucky Ridge Plots (evaluated 9/22/04, 8/30/05, 8/28/06, 8/22/07).

Genus & Species	Accession	Stand Cover %			
		9/22/04	8/30/05	8/28/06	8/22/07
Elymus trachycaulus	Copperhead	61.3 A*	75.0 A*	78.1 A*	47.2 A*
Achnatherum hymenoides	Rimrock	37.2 B	43.4 B	63.1 A	41.3 AB
Poa secunda	Opportunity	30.0 BC	34.1 BC	41.3 B	39.7 ABC
Elymus trachycaulus	9081621	28.4 BCD	25.9 CD	29.4 BC	36.6 ABCD
Elymus trachycaulus	Pryor	26.3 CDE	23.1 CDE	28.1 BCD	31.9 ABCDE
Pascopyrum smithii	9081968	26.3 CDE	22.2 CDEF	26.6 BCDE	31.9 ABCDE
Achnatherum hymenoides	Nezpar	24.1 CDEF	21.9 DEFG	25.3 BCDEF	24.4 BCDEF
Leymus cinereus	9081624	23.8 CDEFG	21.6 DEFG	23.8 BCDEFG	23.8 BCDEF
Elymus wawawaiensis	Secar	23.4 CDEFG	20.9 DEFGH	22.2 CDEFGH	22.5 CDEFG
Elymus trachycaulus	Revenue	22.8 CDEFGH	20.6 DEFGH	21.6 CDEFGHI	19.4 DEFGH
Elymus trachycaulus	San Luis	20.0 DEFGHI	16.2 DEFGHI	19.4 CDEFGHIJ	18.8 DEFGHI
Achnatherum hymenoides	9081628	19.2 DEFGHI	16.2 DEFGHI	17.2 CDEFGHIJ	16.9 EFGHIJ
Pascopyrum smithii	Rosana	19.1 DEFGHI	14.1 DEFGHIJ	14.1 CDEFGHIJ	15.3 EFGHIJ
Leymus cinereus	Trailhead	18.4 EFGHI	14.1 DEFGHIJ	13.4 CDEFGHIJ	15.0 EFGHIJ
Poa secunda	9081635	17.8 EFGHIJ	13.8 DEFGHIJ	12.8 CDEFGHIJ	14.1 EFGHIJ
Pseudoroegneria spicata	9081636	17.5 EFGHIJK	13.8 DEFGHIJ	11.3 CDEFGHIJ	14.1 EFGHIJ
Leymus cinereus	Washoe	16.6 EFGHIJK	13.4 EFGHIJK	10.9 CDEFGHIJ	13.1 FGHIJ
Leymus cinereus	Magnar	15.9 FGHIJKL	13.4 EFGHIJK	10.9 CDEFGHIJ	12.8 FGHIJ
Pascopyrum smithii	Rodan	4.4 FGHIJKLM	13.1 EFGHIJK	10.6 CDEFGHIJ	10.3 FGHIJ
Agrostis gigantea	9081619	14.1 GHIJKLMN	12.5 EFGHIJKL	10.6 CDEFGHIJ	10.0 FGHIJ
Leymus cinereus	9081625	13.4 HIJKLMN	11.9 EFGHIJKLM	9.7 DEFGHIJ	9.1 FGHIJ
Pseudoroegneria spicata	Goldar	13.4 HIJKLMN	11.9 EFGHIJKLM	9.1 EFGHIJ	8.8 FGHIJ
Achnatherum hymenoides	9081629	12.2 IJKLMN	11.1 EFGHIJKLM	7.2 FGHIJ	8.8 FGHIJ
Agrostis gigantea	9076276	11.9 IJKLMNO	10.9 FGHIJKLM	5.9 GHIJ	8.4 FGHIJ
Poa secunda	Sherman	11.6 IJKLMNO	10.6 FGHIJKLM	5.9 GHIJ	7.5 FGHIJ
Poa alpina	01-13--1	11.3 IJKLMNO	10.0 GHIJKLM	4.7 HIJ	7.5 FGHIJ
Deschampsia caespitosa	9076290	8.4 JKLMNOP	9.0 HIJKLM	4.7 HIJ	6.6 FGHIJ
Poa secunda	9081322	7.8 KLMNOP	6.4 IJKLM	4.1 HIJ	5.3 GHIJ
Poa alpina	9016273	6.3 LMNOP	3.9 JKLM	3.4 HIJ	1.6 HIJ
Agrostis gigantea	9076266	5.2 MNOP	3.6 JKLM	3.4 HIJ	0.9 IJ

*Means followed by the same letter are not significantly different at the 0.05 significance level using the LSD Mean Comparison method.

Table 10. Percentage stand cover of grass trials on Stucky Ridge Plots (evaluated 9/22/04, 8/30/05, 8/28/06, 8/22/07) continued.

Genus & Species	Accession	Stand Cover %							
		9/22/04		8/30/05		8/28/06		8/22/07	
Poa alpina	1858	4.4	NOP	3.0	JKLM	2.8	IJ	0.3	J
Deschampsia caespitosa	Nortran	1.9	OP	1.6	KLM	2.8	IJ	0.2	J
Poa alpina	Gruening	1.9	OP	0.9	LM	2.8	IJ	0.00	J
Agrostis gigantea	Streaker	1.1	P	0.8	LM	2.5	J	0.00	J
Poa secunda	Canbar	0.4	P	0.4	M	1.9	J	0.00	J
Deschampsia caespitosa	13970176	0.0	P	0.1	M	0.6	J	0.00	J

*Means followed by the same letter are not significantly different at the 0.05 significance level using the LSD Mean Comparison method.

Table 11. Average plant height of grasses in Stucky Ridge plots (measured 6/30/04, 8/30/05, 8/28/06, 822/07).

Genus & Species	Accession	Height *cm*			
		9/22/04	8/30/05	8/28/06	8/22/07
Elymus trachycaulus	Copperhead	54.4 A*	87.5 A*	78.6 A*	114.1 A*
Elymus trachycaulus	9081621	34.2 C	76.3 A	78.6 A	104.7 A
Agrostis gigantea	9076276	33.3 CD	59.1 B	77.9 A	104.1 A
Agrostis gigantea	9081619	27.1 CDE	58.0 B	77.3 A	88.9 B
Poa secunda	9081633	26.5 CDEF	50.3 BC	74.0 AB	88.4 B
Elymus wawawaiensis	Secar	24.0 DEFG	48.8 BC	70.0 ABC	70.7 C
Poa secunda	9081635	23.3 EFGH	47.7 BC	69.9 ABC	70.3 CD
Pseudoroegneria spicata	Goldar	22.5 EFGHI	47.0 BC	67.9 ABCD	67.3 CDE
Agrostis gigantea	9076266	21.0 EFGHIJ	46.5 BCD	66.3 ABCDE	65.4 CDEF
Elymus trachycaulus	Pryor	18.5 EFGHIJK	45.6 BCDE	64.3 ABCDEF	64.4 CDEF
Leymus cinereus	9081624	17.9 EFGHIJKL	45.5 BCDE	62.4 ABCDEFG	63.1 CDEFG
Poa secunda	9081322	17.5 FGHIJKL	45.4 BCDEF	61.9 ABCDEFGH	62.6 CDEFG
Achnatherum hymenoides	Nezpar	16.9 GHIJKLM	44.7 BCDEF	60.8 ABCDEFGH	61.8 CDEFGH
Leymus cinereus	Trailhead	16.1 GHIJKLMN	43.6 BCDEF	57.3 BCDEFGHI	58.9 CDEFGH
Elymus trachycaulus	San Luis	14.5 HIJKLMNO	39.7 CDEFG	57.1 BCDEFGHIJ	58.4 CDEFGH
Deschampsia cespitosa	9076290	14.5 HIJKLMNO	39.5 CDEFG	57.0 BCDEFGHIJ	55.7 CDEFGH
Elymus trachycaulus	Revenue	14.3 HIJKLMNO	38.9 CDEFG	54.9 CDEFGHIJ	55.3 DEFGH
Pascopyrum smithii	Rosana	13.5 IJKLMNO	38.1 CDEFGH	54.3 CDEFGHIJ	55.1 EFGH
Achnatherum hymenoides	Rimrock	13.0 JKLMNOP	36.9 CDEFGH	52.6 CDEFGHIJ	54.9 EFGH
Leymus cinereus	Magnar	12.8 JKLMNOP	36.7 CDEFGH	50.8 DEFGHIJK	54.8 EFGH
Leymus cinereus	Washoe	12.5 JKLMNOP	36.5 CDEFGH	50.8 DEFGHIJK	54.8 EFGH
Pascopyrum smithii	Rodan	12.3 JKLMNOP	34.9 CDEFGHI	50.0 DEFGHIJKL	53.3 EFGH
Pseudoroegneria spicata	9081636	12.0 JKLMNOP	33.7 CDEFGHI	48.9 EFGHIJKL	52.2 EFGH
Pascopyrum smithii	9081968	11.3 KLMNOP	30.9 DEFGHIJ	48.3 FGHIJKL	51.8 FGH
Leymus cinereus	9081625	10.6 KLMNOP	30.3 EFGHIJK	47.1 FGHIJKLM	50.8 FGH
Agrostis gigantea	Streaker	10.3 KLMNOP	29.8 FGHIJK	46.5 FGHIJKLM	48.8 GH
Achnatherum hymenoides	9081628	9.1 LMNOP	24.7 GHIJKL	46.3 GHIJKLM	48.4 GHI
Poa alpine	1--13—1	8.1 MNOP	24.0 GHIJKL	45.8 GHIJKLM	47.4 HI
Achnatherum hymenoides	9081629	7.6 MNOP	22.8 HIJKL	45.4 GHIJKLM	47.0 HI
Deschampsia cespitosa	13970176	7.0 NOP	20.3 IJKL	44.5 HIJKLM	33.7 IJ
Poa secunda	Sherman	6.8 NOP	17.0 JKL	42.5 IJKLMN	22.9 J
Poa secunda	Canbar	6.0 OP	15.7 JKLM	39.4 JKLMN	21.8 J

Table 11. Average plant height of grasses in Stucky Ridge plots (measured 6/30/04, 8/30/05, 8/28/06, 822/07) continued.

Genus & Species	Accession	Height *cm*							
		9/22/04		8/30/05		8/28/06		8/22/07	
Deschampsia cespitosa	Nortran	6.0	OP	15.0	JKLM	33.00	KLMN	0.00	K
Poa alpina	9016273	5.8	OP	10.8	JKLM	32.67	LMN	0.00	K
Poa alpina	Gruening	4.5	P	9.0	JKLM	30.00	MN	0.00	K
Poa alpina	1858	3.9	P	0.0	M	26.50	N	0.00	K

* Means followed by the same letter are not significantly different at the 0.05 significance level using the LSD Mean Comparison method.

Table12. Percentage vigor of grass trials on Stucky Ridge Plots (evaluated 9/22/04, 8/30/05, 8/28/06, 8/22/07).

Genus & Species	Accession	Vigor* 2004	Vigor* 2005	Vigor* 2006	Vigor * 2007
		1--9	*1--9*	*1--9*	*1--9*
Elymus trachycaulus	Copperhead	2.1	2.1	3.3	4.0
Poa secunda	Opportunity	4.8	2.1	2.9	4.7
Elymus trachycaulus	9081621	3.3	2.7	3.4	4.5
Poa secunda	9081635	3.4	3.3	3.3	3.2
Elymus trachycaulus	Pryor	4.9	5.3	4.8	5.2
Leymus cinereus	9081624	4.9	3.8	4.6	4.5
Pascopyrum smithii	9081968	5.0	4.5	4.0	5.2
Elymus wawawaiensis	Secar	4.4	4.3	4.1	5.1
Elymus trachycaulus	San Luis	4.6	4.6	5.0	4.3
Pascopyrum smithii	Rosana	4.8	4.7	3.7	5.1
Leymus cinereus	Trailhead	4.8	4.3	4.7	5.4
Pascopyrum smithii	Rodan	5.6	5.0	5.0	4.8
Achnatherum hymenoides	9081628	4.8	5.3	4.5	5.3
Achnatherum hymenoides	Rimrock	4.8	4.5	4.4	4.9
Leymus cinereus	9081625	3.3	5.5	5.5	4.6
Pseudoroegneria spicata	9081636	5.2	4.5	4.0	4.9
Agrostis gigantea	9081619	5.0	3.2	4.9	5.5
Leymus cinereus	Washoe	5.2	4.8	4.5	5.0
Agrostis gigantea	9076276	5.3	3.7	4.6	6.2
Poa secunda	Sherman	3.2	4.0	4.4	4.6
Achnatherum hymenoides	Nezpar	5.4	4.6	3.9	5.7
Elymus trachycaulus	Revenue	5.1	5.4	4.7	4.0
Pseudoroegneria spicata	Goldar	5.7	4.6	5.2	5.0
Leymus cinereus	Magnar	2.9	5.2	4.4	5.1
Deschampsia caespitosa	9076290	4.8	3.9	5.1	6.0
Poa secunda	9081322	3.3	4.2	4.9	5.0
Agrostis gigantea	9076266	4.2	4.0	5.5	6.0
Achnatherum hymenoides	9081629	4.3	5.7	4.0	6.8
Poa alpina	01-13-1	4.5	5.0	5.4	5.5
Poa alpina	1858	4.0	5.3	5.5	7.5
Poa alpina	9016273	4.5	3.8	4.8	8.0
Deschampsia caespitosa	Nortran	5.3	3.8	6.1	9.0
Deschampsia caespitosa	13970176	4.0	3.8	5.2	0.0
Poa alpina	Gruening	5.2	1.5	5.0	0.0
Agrostis gigantea	Streaker	6.2	1.5	5.0	0.0
Poa secunda	Canbar	5.5	8.0	4.5	0.0

*1–9 rating scale with 1 being the best.

Table 13. Biomass production of grasses in Stucky Ridge Trials (clipped 9/22/04, 8/30/05, 8/28/06, 8/22/07).

Genus & Species	Accession	Biomass 2004	Biomass 2005	Biomass 2006	Biomass 2007
		kg/ha	*kg/ha*	*kg/ha*	*kg/ha*
Elymus trachycaulus	Copperhead	2,083 A*	8,211 A*	4894.4 A*	3583.3 A*
Agrostis gigantea	9081619	706 B	4,100 B	3322.2 AB	2261.1 B
Elymus trachycaulus	9081621	544 BC	2,506 C	2633.3 BC	2205.6 BC
Elymus wawawaiensis	Secar	413 BCD	2,222 CD	2311.1 BCD	2011.1 BCD
Poa secunda	Opportunity	408 BCD	2,189 CD	2311.1 BCD	1511.1 BCDE
Elymus trachycaulus	Pryor	386 BCDE	2,039 CDE	2255.6 BCDE	1466.7 CDEF
Leymus cinereus	9081624	333 CDEF	1,844 CDEF	2172.2 BCDE	1261.1 DEFG
Leymus cinereus	Washoe	289 CDEF	1,578 CDEFG	1988.9 BCDEF	1194.4 EFGH
Agrostis gigantea	9076276	287 CDEF	1,367 CDEFGH	1761.1 BCDEFG	972.2 EFGHI
Elymus trachycaulus	Revenue	266 CDEF	1,289 CDEFGH	1550.0 CDEFGH	938.9 EFGHI
Poa secunda	9081635	216 CDEF	906 DEFGH	1550.0 CDEFGH	927.8 EFGHI
Deschampsia caespitosa	9076290	193 CDEF	872 DEFGH	1272.2 CDEFGH	850.0 EFGHIJ
Leymus cinereus	Trailhead	192 CDEF	844 DEFGH	1216.7 CDEFGH	738.9 EFGHIJK
Agrostis gigantea	9076266	185 DEF	800 DEFGH	1150.0 CDEFGH	694.4 FGHIJK
Poa secunda	Sherman	183 DEF	650 EFGH	1072.2 CDEFGH	650.0 GHIJK
Achnatherum hymenoides	Nezpar	169 DEF	639 EFGH	1022.2 CDEFGH	638.9 GHIJK
Pseudoroegneria spicata	Goldar	165 DEF	622 EFGH	1000.0 CDEFGH	588.9 GHIJK
Pascopyrum smithii	9081968	127 DEF	578 FGH	922.2 DEFGH	583.3 GHIJK
Leymus cinereus	9081625	124 DEF	428 FGH	777.8 DEFGH	550.0 GHIJK
Elymus trachycaulus	San Luis	100 DEF	361 GH	677.8 DEFGH	550.0 GHIJK
Pseudoroegneria spicata	9081636	97 DEF	339 GH	622.2 EFGH	455.6 HIJK
Pascopyrum smithii	Rosana	95 DEF	317 GH	461.1 FGH	427.8 HIJK
Poa alpina	01-13-1	92 DEF	272 GH	455.6 FGH	366.7 IJK
Pascopyrum smithii	Rodan	85 DEF	233 GH	444.4 FGH	338.9 IJK
Achnatherum hymenoides	Rimrock	84 DEF	189 GH	400.0 FGH	311.1 IJK
Poa alpina	9016273	80 DEF	189 GH	305.6 GH	277.8 IJK
Leymus cinereus	Magnar	75 DEF	122 H	294.4 GH	138.9 JK
Deschampsia caespitosa	Nortran	73 DEF	61 H	177.8 GH	122.2 JK

*Means followed by the same letter are not significantly different at the 0.05 significance level using the LSD Mean Comparison method.

Table 13. Biomass production of grasses in Stucky Ridge Trials (clipped 9/22/04, 8/30/05, 8/28/06, 8/22/07), continued.

Genus & Species	Accession	Biomass 2004		Biomass 2005		Biomass 2006		Biomass 2007	
		kg/ha		*kg/ha*		*kg/ha*		*kg/ha*	
Achnatherum hymenoides	9081628	34	EF	61	H	138.9	GH	122.2	JK
Poa secunda	9081322	24	F	51	H	122.2	GH	66.7	K
Achnatherum hymenoides	9081629	23	F	28	H	88.9	GH	44.5	K
Poa alpina	Gruening	15	F	28	H	83.3	H	11.1	K
Deschampsia caespitosa	13970176	8	F	23	H	77.8	H	0.0	K
Poa alpina	1858	7	F	0	H	72.2	H	0.0	K
Agrostis gigantea	Streaker	0	F	0	H	38.9	H	0.0	K
Poa secunda	Canbar	0	F	0	H	5.6	H	0.0	K

*Means followed by the same letter are not significantly different at the 0.05 significance level using the LSD Mean Comparison method.

Seed Mixture Trial

The forbs included in the seed mixtures did not emerge; therefore, densities reflect only emergent grass seedlings (Tables 5, 6, 7, and 8). During the establishment year, the Developed Waste Management Area (WMA) mix had the greatest seedling density with 113.0 seedlings/m^2 (Table 14). The Experimental WMA mix had the lowest density with 67.8 seedlings/m^2. Developed mixtures averaged 100.1 seedlings/m^2. Experimental mixtures averaged 68.4 seedlings/m^2. There were no significant differences among the mixtures at the P=0.05 level. By the fall of 2003, the Developed WMA mixture still had the highest density (86.1 seedlings/m^2) and the Experimental WMA mixture the lowest density (74.3 seedlings/m^2). The Developed mixtures averaged 80.8 seedlings/m^2 and the Experimental mixtures averaged 77.0 seedlings/m^2. As in June, no significant differences were seen among the four seed mixtures.

At the start of the second growing season (2004), the Experimental mixes had significantly better stand cover (Upland Exp.—39.4% and Waste Mgmt. Exp.—38.1%) than the Developed mixes (Upland Dev.—17.3 and Waste Mgmt. Dev.—15.0%). By the fall of 2004, the stands of all the mixes had increased, but the Experimental mixes were still significantly better than the Developed mixes. Biomass production of the Experimental mixes was also significantly better than the Developed mixes.

During the third year (2005), the percentage stand cover of all mixes increased only slightly, but the biomass production was much higher. The Experimental mixes were dominated by Copperhead slender wheatgrass, while the Developed mixes were dominated by Revenue slender wheatgrass and Critana thickspike wheatgrass. The Waste Management Experimental mix topped all mixes with 8,933 kg/ha of oven-dry biomass production.

Growing season 2006 took a different approach as the percentage stand cover increased in all but the Upland Experimental mix. Biomass production of all mixes had decreased, but the Waste Management mixes dominated over the Upland mixes. The biomass decrease averaged 34.5% for the Experimental mixes and 81.2% for the Developed mixes. Overall, the grass mixes were doing well and 2006 was a recovery year when compared to 2005's high biomass production.

In season 2007, all percentages declined. The Waste Management mixes had better stand cover and biomass averages than the Upland Experimental mixes, but the Upland Experimental

mixes had a better height average. Overall, the mixes were free of non-crop plants and looked healthy.

Table 14. Moto-X Replicated Mixture Trial on Stucky Ridge.

Mix	Density *no/m²*		Stand Cover *%*					Height *cm*				Biomass *kg/ha*			
	6/03	8/03	6/04	9/04	8/05	8/06	8/07	2004	2005	2006	2007	2004	2005	2006	2007
Upland Exp.	68.9	79.7	39.4	45.9	60.6	49.7	27.8	45.8	78.8	75.3	68.0	790	5939	1367	1083.3
Upland Dev.	100.1	75.4	17.3	24.4	25.9	35.9	27.2	14.8	47.2	57.6	70.5	215	2011	1783	1683.3
Waste Mgmt Area Exp	67.8	74.3	38.1	46.9	59.7	65.0	34.1	44.8	82.5	76.3	67.0	1206	8933	4106	1772.2
Waste Mgmt Area Dev	113.0	86.1	15.0	23.8	28.4	38.1	26.3	19.8	56.6	72.3	68.1	306	4494	3311	1388.9

Forb/Subshrub Trial

Eleven of the 16 trial entries had no emergence and 15 of the 16 entries had <5.4 seedlings/m^2 the seedling year (Table 15). The subshrub, winterfat (*Krascheninnikovia lanata*) Open Range Germplasm, was the only entry demonstrating significant emergence with 101.9 seedlings/mm^2. The lack of forb emergence may be due to the late May 13 planting date. Forb species in the study may have some physiological (after ripening) or physical (hard seed coat) seed dormancy. To overcome seed dormancy, many forb seeds generally require several weeks (8 to 14 weeks) of cold chilling. As with the grass species, some additional germination and emergence was expected in the spring of 2004, but did not happen with the forb species. Some species, such as thickstem aster (*Symphyotrichum chilense*) and buckwheat (*Eriogonum* sp.), do better with shallow seeding. By the second growing season, only plants of Open Range winterfat and 9081632 silverleaf phacelia remained alive. There was no sign of new emergence of any of the accessions/species in the spring of 2004. The surviving, mature plants of Open Range Germplasm winterfat performed well, with some plants flowering and setting seed. After the third growing season (2005), plants of Open Range winterfat, 9081632 silverleaf phacelia, Old Works fuzzytongue penstemon, Richfield firecracker penstemon, and Northern Cold Desert winterfat were found to be surviving. New plants of firecracker penstemon and fuzzytongue penstemon had germinated two years after being planted. The surviving plants of Open Range

winterfat and 9081632 silverleaf phacelia exhibited good vigor, growth, and seed production. In 2006, the only surviving plants were the Open Range winterfat and Old Works fuzzytongue penstemon, with both showing good vigor and seed production. In 2007, the only plants surviving were Open Range winterfat and 9081632 silverleaf phacelia. The Old Works fuzzytongue penstemon and silverleaf phacelia seem to be surviving every other year, more than likely through their individual seed production. Open Range winterfat and 9081632 silverleaf phacelia showed good vigor and better than average seed production.

Tissue Analysis

Following the Fall 2004 and Fall 2005 evaluations for cover and vigor, each individual plot was sampled for biomass production. These clippings from all four replications, along with additional clipping of low producing plots, made up the 10 gram or greater, oven-dry samples submitted for tissue analysis. Samples were submitted to Energy Laboratories, Inc. in Billings, Montana, for determination of heavy-metal concentrations in and on sampled plant materials from the Stucky Ridge Moto-X site (Table 16). Metal loads (concentration in and on the plant tissue) can be compared to maximum tolerable levels of dietary minerals for domestic animals (National Research Council 1980). The dietary level of cadmium for domesticated animals is based on human food residue considerations (NRC, 1980) and the need to avoid increases of cadmium in the food supply of the United States. Higher residue levels (>0.50 mg/kg for a short period of time) would not be expected to be harmful to animal health nor to human food use, particularly if the animals were slaughtered at a young age. Based on a review of the scientific literature, ranges of elemental levels for mature leaf tissue have been presented by Kabata-Pendias and Pendias (1992). The authors provide elemental levels for generalized plant species into ranges representing deficient, sufficient, normal, and excessive or toxic (Table 16).

All tissue samples are unreplicated composites of samples from random plants in all four replications of the Stucky Ridge Comparative Evaluation Trial. Metal loads in the sampled tissue were generally below toxic levels.

Arsenic—Arsenic was detected in 19 of the 39 samples in 2004, 32 of the 40 samples in 2005, and 3 of the 42 samples in 2006. Levels ranged from 5 mg/kg to 35 mg/kg, which is below the tolerable levels for domestic livestock (50 mg/kg) and wildlife (50 mg/kg). However, the detected levels rank in the ‘Excessive or Toxic’ level in plants.

Table 15. Seedling density (2003), percentage stand cover (2004), and total plant density (2005) of forb and subshrub accessions in the Comparative Stucky Ridge Evaluation Planting (evaluated 6/24/03, 8/25/03, 6/30/04, 9/22/04, 8/30/05, 8/29/06, and 8/22/07).

Genus & Species	Variety/Accession	Species ID	2003 Density/m^2 6/24	8/25	2004 Stand Cover 6/30	9/22	2005 Avg. Plants/ Plot 8/30	2006 Avg. Plants/ Plot 8/28	2007 Avg. Plants/ Plot 8/22
					%	%			
Krascheninnikovia lanata	Open Range Germplasm	5	101.9 a*	6.8 a*	5.5 a*	4.5 a*	20.0	17	12.8
Phacelia hastata	9081632	10	0.3 b	0.2 b	0.5 b	0.5 b	6.0	0	2
Krascheninnikovia lanata	Northern Cold Desert Germ.	4	0.2 b	0.2 b	0.0 b	0.0 b	0.3	0	0
Penstemon strictus	'Bandera'	8	0.2 b	0.0 b	0.0 b	0.0 b	0.0	0	0
Eriogonum umbellatum	9082271	2	0.1 b	0.0 b	0.0 b	0.0 b	0.0	0	0
Penstemon venustus	Clearwater Selected	9	0.0 b	0.0 b	0.0 b	0.0 b	0.0	0	0
Eriogonum umbellatum	9082273	3	0.0 b	0.0 b	0.0 b	0.0 b	0.0	0	0
Penstemon eatonii	Richfield Select	7	0.0 b	0.0 b	0.0 b	0.0 b	0.8	0	0
Eriogonum ovalifolium	9082098	1	0.0 b	0.0 b	0.0 b	0.0 b	0.0	0	0
Penstemon eriantherus	Old Works Germplasm	6	0.0 b	0.0 b	0.0 b	0.0 b	15.0	10	0
Phacelia hastata	9082275	11	0.0 b	0.0 b	0.0 b	0.0 b	0.0	0	0
Potentilla gracilis	9081679	12	0.0 b	0.0 b	0.0 b	0.0 b	0.0	0	0
Potentilla hippiana	9076274	13	0.0 b	0.0 b	0.0 b	0.0 b	0.0	0	0
Symphyotrichum chilense	9078675	14	0.0 b	0.0 b	0.0 b	0.0 b	0.0	0	0
Symphyotrichum chilense	9081678	15	0.0 b	0.0 b	0.0 b	0.0 b	0.0	0	0
Symphyotrichum chilense	9082274	16	0.0 b	0.0 b	0.0 b	0.0 b	0.0	0	0

* Means followed by the same letter are similar at the 0.05 level of significance using the LSD Mean Comparison method.

Cadmium—In 2004, the element was detected in only one sample (Rimrock Indian ricegrass), but in 2005 it was detected in five samples (three of which were in Indian ricegrasses). In 2006, there was no detection of cadmium in any sample. The detected level, 1-2 mg/kg, is at the tolerable level for domestic livestock (0.5 mg/kg) and wildlife (2 mg/kg).

Copper—Copper was detected in all tissue samples and ranged from 5 mg/kg to 307 mg/kg. Only three samples (2004), five samples (2005), and no samples (2006) exceeded the tolerable level (100 mg/kg) for domestic livestock, but 15 samples (2004), 19 samples (2005), and one sample (2006) exceeded the tolerable level (55 mg/kg) for wildlife. Since this is a Cu smelting impacted area, high levels of copper are to be expected.

Lead—Lead was detected in a sample of ten-petal blazing star (*Mentzelia decapetala)* only in 2004, at a level of nine mg/kg, well below the tolerable level for domestic livestock and wildlife. In 2005, lead was detected in only four samples and at very low levels. In 2006, lead was detected in two samples and one sample rated in the "Excessive or Toxic" level in plants.

Zinc—Zinc was detected in all samples, ranging from 9 mg/kg to 175 mg/kg, which is well below the tolerable level, 500 mg/kg, for domestic livestock and 300 mg/kg for wildlife. In 2006, Zn was detected in all samples, but with low levels. The levels ranged from 9 to 35 mg/kg except for LECI Trailhead, which had a level of 125 mg/kg, which is still well below the tolerable levels for domestic livestock and wildlife and in the normal level for plants.

Worth noting was the fact heavy metal concentrations were highest in/on alpine blue grass, silverleaf phacelia, winterfat and fuzzytongue penstemon. This is likely due to the excess dust particles on the low profile plants and those species exhibiting leaf pubescence.

In 2007, Zn was still detected in all samples, but in normal levels. The levels ranged from 8 to 53 mg/kg. Copper was found in most samples and those levels were in the normal range for plants and animals. Arsenic was found in five samples, with all of them in the excessive level for plants, but in the tolerable level for domestic animals and wildlife. There were no detectable levels found of Cd or Pb found in any of the plant samples. Soil samples were taken and analysis results showed the pH and As stayed fairly close to the same levels when compared to the 2003 samples, but Cd, Cu, Pb, and Zn levels all went up (Table 17).

Table 16. Heavy metal concentrations of clipped biomass samples from the Stucky Ridge Comparative Evaluation Trials (sampled 9/22/04, analyzed 11/10/04).

Plot No.	Genus/Species/Accession	Al	As	Cd	Cu	Pb	Zn
		mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
	Mentzelia decpetala	1240	13	ND	78	9	70
	Erysimum sp.	125	ND	ND	24	ND	91
1	Achy 9081628	331	6	ND	39	ND	123
2	Achy 9081629	288	9	ND	41	ND	111
3	Achy Rimrock	235	ND	5	17	ND	68
4	Achy Nezpar	276	ND	ND	16	ND	51
5	Aggi 9076276	258	ND	ND	46	ND	54
6	Aggi 9081619	663	ND	ND	100	ND	51
7	Aggi 9076266	548	ND	ND	74	ND	100
8	AGGI Streaker	No Sample					
9	Dece 9076290	334	5	ND	48	ND	63
10	Dece 13970176	1420	8	ND	57	ND	87
11	Dece Nortran	336	8	ND	29	ND	67
12	Eltr 9081620	242	ND	ND	26	ND	14
13	Eltr 9081621	197	ND	ND	38	ND	21
14	Eltr Pryor	301	ND	ND	25	ND	37
15	Eltr Revenue	280	ND	ND	48	ND	50
16	Eltr San Luis	441	ND	ND	45	ND	40
17	Leci 9081624	424	ND	ND	62	ND	111
18	Leci 9081625	463	6	ND	72	ND	172
19	Leci Washoe	472	7	ND	47	ND	175
20	Leci Magnar	636	11	ND	113	ND	84
21	Leci Trailhead	441	ND	ND	35	ND	85
22	Pasm 9081968	374	6	ND	45	ND	86
23	Pasm Rodan	495	7	ND	52	ND	56
24	Pasm Rosana	210	6	ND	29	ND	61
25	Poal 9016273	799	7	ND	50	ND	45
26	Poal 01-13-1	1220	8	ND	78	ND	49
27	Poal Gruening	706	ND	ND	40	ND	36
28	Poal 1858	1190	ND	ND	33	ND	62
29	Pose 9081633	442	9	ND	49	ND	35
30	Pose Sherman	311	9	ND	36	ND	94
31	Pose Canbar	No Sample					
32	Posp 9081635	364	11	ND	46	ND	38
33	Posp 0981322	441	ND	ND	83	ND	57
34	Pssp 9081636	676	16	ND	76	ND	81
35	Pssp Goldar	654	13	ND	81	ND	77
36	Elwa Secar	396	ND	ND	34	ND	68
	Open Range Rep 1	922	ND	ND	91	ND	77
	Open Range Rep 2	1240	14	ND	111	ND	63
	Open Range Rep 3	921	6	ND	95	ND	113
	Open Range Rep 4	1610	10	ND	136	ND	75
1	Up Exp Rep 4	392	ND	ND	51	ND	22
2	Up Dev Rep 3	268	ND	ND	31	ND	73
3	WMA Exp Rep 3	374	ND	ND	35	ND	27
4	WMA Dev Rep 4	270	ND	ND	26	ND	67

Table 16. Heavy metal concentrations of clipped biomass samples from the Stucky Ridge Comparative Evaluation Trials (sampled 9/22/04, analyzed 11/10/04), continued.

	As	Cd	Cu	Pb	Zn
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
Maximum Tolerable Levels for	50	0.5	100	30	500
Domestic livestock 1.					
Wildlife 2.	50	2	55	40	300
Metal levels in Plants 3.					
Deficient			2 to 5		10 to 20
Sufficient or Normal	1 to 1.7	0.05 to 0.2	5 to 30	5 to 10	27 to 150
Excessive or Toxic	5 to 20	5 to 30	20 to 100	30 to 300	100 to 400
1. NRC 1980, 2. Ford, 1996, 3. Kabata-Pendias and Pendias 1992.					

Table 17. Post-planting soil samples from the Stucky Ridge Comparative Evaluation Planting. Samples taken on 6/24/03 and on 8/22/07.

Sample Description	pH *s.u.*		As *mg/kg*		Cd *mg/kg*		Cu *mg/kg*		Pb *mg/kg*		Zn *mg/kg*	
	2003	2007	2003	2007	2003	2007	2003	2007	2003	2007	2003	2007
Grass trial, Rep 1	8.2	8.3	120	97	1	2	797	788	35	45	174	201
Grass trial, Rep 2	8.1	8.1	117	219	1	3	906	1540	34	76	177	282
Grass trial, Rep 3	7.9	8.1	132	132	1	3	833	1090	43	47	195	216
Grass trial, Rep 4	8.0	6.2	212	214	2	3	985	1190	61	79	228	254
Forb trial, Rep 1	8.0	7.5	115	366	1	3	774	1570	38	138	185	378
Forb trial, Rep 4	7.6	7.2	127	158	2	3	1080	1280	40	64	210	231

CONCLUSION

Not all of the potentially viable seeds germinated the first year (2003). The record high temperatures and low precipitation in July and August, along with the late spring planting date (May 13), are considered to be the primary factors affecting the incomplete germination and emergence during the 2003 growing season. There was a significant amount of new grass seedling emergence detected during the 2004 evaluation, particularly in the Indian ricegrass, western wheatgrass, Nevada bluegrass, and basin wildrye plots and some new germination of forbs in 2005.

In the single-species plots, the 'local source' plants that exhibited superior performance include Copperhead and 9081621 slender wheatgrass, (9081633) Opportunity Nevada bluegrass, 9081968 western wheatgrass, 9081624 and Washoe Germplasm basin wildrye, 9081628 Indian ricegrass, 9081636 bluebunch wheatgrass, and 9081635 Canbyi bluegrass. Superior indigenous

plant material is being further increased for potential release to the commercial seed industry. Worth noting was the performance of some of the released cultivars such as Pryor and Revenue slender wheatgrass, Rosana western wheatgrass, Rimrock Indian ricegrass, Trailhead basin wildrye, Secar Snake River wheatgrass, and Goldar bluebunch wheatgrass.

The forb/subshrub trial had poor emergence and consequently poor seedling densities with the exception of Open Range Germplasm winterfat. Low densities were most likely the result of the late spring planting that resulted in an insufficient period of cold-moist stratification. Two additional factors may have been sowing small-sized seed too deeply and heavy surface erosion on this portion of the trial site.

In the Seed Mixture Trials, the 'Experimental' mixes that contained native 'local source' were far superior to the 'Developed' mixes that consisted of native 'nonlocal source' (Upland mix) and introduced cultivars (Waste Management Areas). However, it was estimated the majority of plants in the Experimental mixtures, both Upland and Waste Management Areas, were Copperhead slender wheatgrass, which was the best overall performer on this particular site.

The tissue analyses show the heavy metal concentrations in and on the plant tissue sampled from the Stucky Ridge plots were generally within the tolerable limits for both domestic livestock and wildlife.

The overall performance on the Stucky Ridge plots was quite variable, with strips running north and south having poorer plant vigor and biomass production. The Pryor slender wheatgrass strips, between replications (running east and west), exhibited waves of good and poor establishment and performance. Soil samples (0-15 cm) were taken under four plant stands of slender wheatgrass, ranging from excellent to very poor in stand cover, in hopes of explaining this variability. It was thought the incorporation of the amendments may have created strips with varying pH. Soil analysis for pH indicated no difference in pH (6.8 to 7.3 in 2003 and 6.2 to 8.3 in 2007) under the varying stands of slender wheatgrass. Therefore, the variability is still unexplained.

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