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PLANT MATERIALS TECHNICAL NOTE

Native Grass Establishment and Performance for Well-Pad Reclamation in Wyoming

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Figure 1. A 3.8 acre gas exploration well pad near Pinedale, Wyoming. The un-vegetated area around the drill rig will be reclaimed after exploration is completed.

INTRODUCTION

One question when reclaiming highly disturbed sites (see Figure 1) is, "what species to seed?" Species selection is based on management goals, climate, topography, soils, and resource concerns. Matching site and climate conditions is particularly important when choosing native species because they generally have narrower ranges of adaptation than non-native species. However, many commercially available native grasses have not been tested under a variety of harsh site conditions. The first objective of this field planting was to test the establishment success of 12 native grass species seeded on a critical area (highly disturbed) site under relatively harsh growing conditions. Although all species tested in this planting are represented in nearby plant communities, we expected them to have different levels of establishment success.

The second objective of this field planting was to determine if varieties or accessions of the same species established differently under the conditions of the site. Some of the native grass species selected for testing have multiple varieties or cultivars available from the commercial seed market, or have accessions under development, and variable performance was predicted. Performance information will help planners determine if a certain variety or cultivar should be specified in a seeding plan at least for this ecological site or sites with similar conditions. We expected accessions or cultivars of a species to have different establishment rates.

METHODS

Field Planting Site

We tested the establishment of 12 native grass species on a 3.8-acre gas exploration well-pad in Sublette County, Wyoming, approximately 30 miles south of Pinedale (N ½ SW ¼, Section 10, T29N R107W) at 7,195 feet elevation. The site, developed by Shell Exploration and managed by the United States Department of Interior (USDI), Bureau of Land Management (BLM), is within spring-summer-fall habitat for pronghorn antelope and year-round habitat for sage grouse. Resource concerns include prevention of erosion and restoration of wildlife habitat fragmented by gas exploration. Located in Major Land Resource Area (MLRA) 34A Cool Central Desertic Basins and Plateaus, the ecological site correlation is Loamy 7-9 Green River Basin. The soil is mapped as 5507 Diamondville-Cotha complex and described as a loam and light-clay loam in the top 12 inches with slope ranging from one to 10 percent. The 30-year average annual precipitation is approximately 10 inches. The mean monthly temperature and precipitation from two stations in the area from 2006 to 2010 (the period of the field planting) are listed in Table 1. It shows warmer and drier growing season conditions than the long-term average during the first two establishment years (2006 and 2007) and wetter than normal growing season conditions in 2009 and 2010.

Table 1. The mean monthly temperature (F) and precipitation (inches), and the 30-year average precipitation (LT Average), averaged over two climate sites, Pinedale at 7,195 feet elevation and La Barge at 6,595 feet elevation. Missing data one or both sites is indicated by M.

Month	2006		2007		2008		2009		2010		LT Average	
	Temp	Precip	Temp	Precip	Temp	Precip	Temp	Precip	Temp	Precip	Temp	Precip
January	15.1	0.60	9.0	0.26	5.5	0.76	18.6	0.76	14.2	0.43	12.8	0.57
February	11.9	0.61	22.9	0.45	14.0	0.90	18.4	0.42	16.2	0.08	16.5	0.55
March	24.5	0.57	34.0	0.59	23.0	0.26	27.2	0.63	31.5	0.43	26.6	0.60
April	39.9	0.49	38.9	0.52	32.3	0.29	37.5	1.12	36.9	1.56	36.3	0.90
May	47.7	0.27	47.7	0.53	45.0	2.19	47.7	1.12	40.6	1.10	46.1	1.63
June	58.0	0.70	59.7M	0M	54.1	0.32	53.2	3.37	54.4	1.33	54.8	0.98
July	70.0	0.38	67.5	0.8	63.7	0.06	61.6	0.62	61.7	0.36	61.2	1.04
August	59.2	0.47	62.6	1.88	60.8	0.62	58.8	0.69	59.7	1.69	59.3	0.96
September	49.3	1.26	51.9	1.73	49.9	1.02	54.8	0.51	52.1	0.09	50.1	1.00
October	40.0	1.17	41.2	0.75	40.35	1.00	34.8	1.28	M	M	39.2	0.69
November	26.0	0.61	29.4	0.08	32.8	0.23	28.4	0.02	M	M	24.4	0.63
December	16.7	0.53	12.3	0.78	16.7	0.83	9.7	0.30	M	M	14.3	0.48
Mean/Total	39.0	7.64	M	8.37M	36.5	8.46	37.5	10.82	M	M	36.8	10.03

The reference plant community is sagebrush steppe with 30 to 70 percent grass and grass-like plants, 5 to 15 percent forbs, and 10 to 30 percent woody plants. The expected predominant grass species are needle and thread (*Hesperostipa comata*), thickspike wheatgrass (*Elymus lanceolatus*), Indian ricegrass (*Achnatherum hymenoides*), bluebunch wheatgrass (*Pseudoroegneria spicata*), and bottlebrush squirreltail (*Elymus elymoides*). Forbs often include hoary tansyaster (*Machaeranthera canescens*), buckwheat (*Eriogonum* spp.), fleabane (*Erigeron* spp.), Hood’s phlox (*Phlox hoodii*), longleaf phlox (*Phlox longifolia*), hollyleaf clover (*Trifolium gymnocarpon*), milkvetch (*Astragalus* spp.), pussytoes (*Antennaria* spp.), stemless mock goldenweed (*Stenotus aqualis*), rock cress (*Arabis* spp.), and desert parsley (*Lomatium* spp.). Shrubs include Wyoming big sagebrush (*Artemisia tridentata*), yellow rabbitbrush (*Chrysothamnus viscidiflorus*), granite prickly phlox (*Linanthus pungens*) and winterfat (*Krascheninnikovia lanata*). The potential total annual production (air-dry weight) ranges from 300 pounds per acre (lb./ac.) in unfavorable years up to 700 lb./ac. in favorable years with 500 lb./ac. expected in average years.

The well pad was constructed in 2002 and reclaimed in 2005. The top soil salvaged from the upper six inches of the profile was stockpiled for 37 months during exploration activities then evenly redistributed across the site once drilling was completed. The site was ripped to a depth of 12 inches to mitigate compaction then smoothed and firmed using a cultipacker for the finished seed bed which was described as moderately fluffy. The site was fenced to restrict large ungulate grazing.

Species and Seeding

The native grass species and accessions tested are listed in Table 2. Nomenclature is based on the PLANTS database). All species, with the exception of sheep fescue, are considered native to plant communities in Sublette County, Wyoming.

Table 2. Grass species (symbol) and their accessions seeded on the gas exploration well pad near Pinedale Wyoming.

Scientific name	Common name	Cultivars (accession)	Origin
Achnatherum hymenoides ACHY	Indian ricegrass	'Rimrock'	Yellowstone Co., MT
		'Nezpar'	Whitebird, ID
Elymus elymoides (ELEL5)	bottlebrush squirreltail	Pueblo	Pueblo Co., CO
		Wapiti	Rio Blanco Co., CO
		9019219	Washakie Co., WY
Elymus lanceolatus (ELLA3)	thickspike/streambank wheatgrass	'Bannock'	ID, OR, WA composite
		'Critana'	Hill Co., MT
		'Sodar'	Grant Co., OR
Elymus trachycaulus (ELTR7)	slender wheatgrass	Copperhead	Deer Lodge Co., MT
		'Pryor'	Carbon Co., MT
		'San Luis'	Rio Grande Co., CO
Elymus wawawaiensis (ELWA2)	Snake River wheatgrass	E-45	WA OR composite
		'Secar'	Lewistown, ID
Festuca ovina (FEOV)	sheep fescue	'Covar'	Central Turkey
Koeleria macrantha (KOMA)	prairie Junegrass	9087539	Common unknown origin
Leymus cinereus (LECI4)	basin wildrye	'Continental'	Magnar Trailhead hybrid
		L-46	CAN OR hybrid
		'Magnar'	Saskatchewan, CAN
		'Trailhead'	Musselshell Co., MT
		'Washoe'	Deer lodge Co., MT
Leymus salinus (LESA4)	saline wildrye	9043501	Colfax Co., NM
Pascopyrum smithii (PASM)	western wheatgrass	'Rodan'	Morton Co., ND
		'Rosana'	Rosebud Co., MT
Poa secunda (POSE)	Sandberg bluegrass	'High Plains'	MT WY composite
		'Opportunity'	Deer Lodge Co., MT
		'Sherman'	Sherman Co., OR
		9092261	Sherman Co., OR
Pseudoroegneria spicata (PSSP6)	bluebunch wheatgrass	'Anatone'	Anatone, WA
		P-24	Lind, WA
		'Goldar'	Asotin Co., WA
		P-19	Interior Pacific NW
		P-22	Origin unknown

The accessions of species were seeded individually into 4 by 20-foot plots on October 19, 2005 using a precision plot seeder calibrated to deliver approximately 30 pure live seeds (PLS) per linear foot at 12-inch row spacing resulting in four rows per plot (see Figure 2). Fifty PLS per square foot is the seeding rate in the Wyoming NRCS Critical Area Specification (2012) based on Wyoming Plant Materials Technical Note WYPM3; Perennial Vegetation Establishment Guide, Species, Cultivars, and Seeding Rates (see Montana Plant Materials Technical Note MT-46, Seeding Rates and Recommended Cultivars). Each accession was assigned at random to plots within each of four replications for a randomized complete block experimental design.

Figure 2. Drill-seeding the Shell-Pinedale Field Planting October 19, 2005.

Evaluation

Plots were evaluated (see Figure 3) for establishment by counting the number of seeded plants within three randomly selected one-foot lengths of the middle two drill rows for a total of six sub-samples. Densities were counted on September 9, 2007, July 29, 2008, July 28, 2009, and July 27, 2010. At the time of the density counts, each plot was visually evaluated for overall stand establishment on a scale from one to nine where plots with few grasses established were rated nine and where rows were completely filled were rated one. The data were inverted for analysis so plots with no establishment were assigned zero and plots with full establishment assigned nine. Vigor of plants established in the plots was similarly rated on a scale from one to nine where plants with perceived low vigor were rated nine and a one rating was the perceived potential of the established plants for the site. The vigor estimates were also inverted for analysis and a zero assigned where no seeded grasses established. Also, height measurements were taken on representative un-grazed plants. Overall stand establishment and plant vigor were also estimated by clipping biomass. Biomass of the current year's growth was clipped from the middle 16 feet of the two central drill rows of each plot on July 29, 2008 and July 27, 2010 and from the middle 16 feet of the outer two drill rows on July 28, 2009, collecting annual production from 32 square feet in each plot. The clippings were dried to constant weight and weighed. Data were analyzed using analysis of variance (ANOVA). The details of the ANOVA models and the ANOVA tables showing *P*-values are in Appendix A.

Figure 3. Evaluating Grass Plots at the Shell-Pinedale Field Planting July 28, 2010.

RESULTS

Density

The densities by year for each grass species are presented in Figure 4. The ANOVA found densities were affected by year (*P*<0.0001). Considering all species grouped together, the most plants were counted in 2007 (1.5 plants per square foot), followed by 2008 (1.4 plants per square foot), then 2010 (1.0 plants per square foot), and lowest in 2009 (0.8 plants per square foot). The only statistically significantly differences were 2007 densities were greater than 2009 and 2010, and 2008 densities were greater than 2009. Under ideal establishment conditions, we would expect density to be greatest in the establishment year (20 plants per square foot) and decline over time from self-thinning. However, compared to the long-term average, growing season temperatures were warmer, and precipitation was less during establishment in 2006, and in 2007, (see Table 1) which likely is responsible for the low seedling emergence and survival (1.5 plants per square foot) during that time.

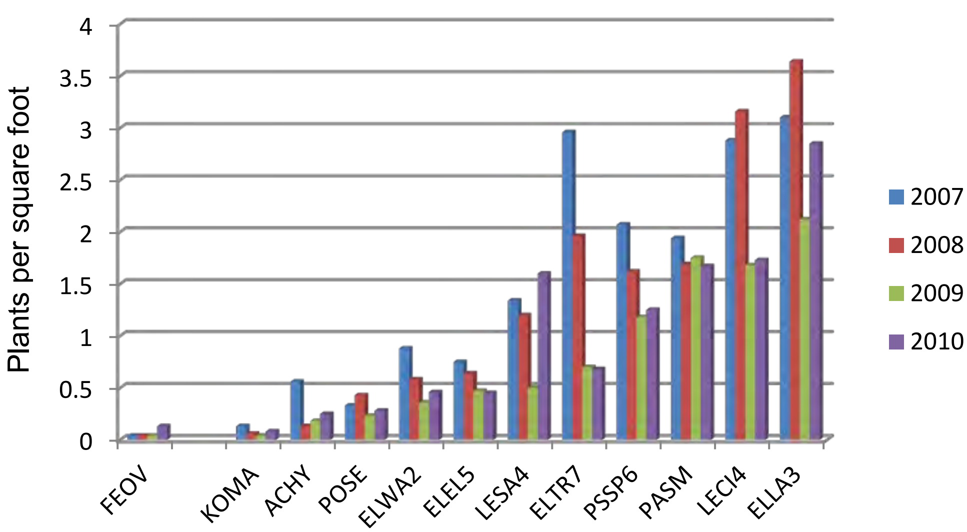

Figure 4. The mean density values for seeded grasses by year at the Shell-Pinedale Field Planting (see Table 2 to match symbols with species).

Densities were also affected by the species seeded (*P*<0.0001). Thickspike wheatgrass (including streambank wheatgrass) had the greatest density followed by basin wildrye, western wheatgrass, slender wheatgrass, and bluebunch wheatgrass, all of which had significantly greater densities than prairie Junegrass, Sandberg bluegrass, Indian ricegrass, and bottlebrush squirreltail (see Table 3). Wyoming Plant Materials Tech Note 10; Determining Success of Seedings (2003) defines one to two plants per square foot is adequate for erosion control on dryland conditions for both bunchgrasses and sod-forming grasses. These results support recommending any of the top six species for reclamation of disturbed sites in this area. This would allow for a diverse seed mix except there would not be an early season grass (e.g., Sandberg bluegrass) or a mid-seral species (e.g., bottlebrush squirreltail) both of which we expected higher densities. Indian ricegrass also had low densities perhaps because of seed dormancy; however, its density did not increase over time as might be expected if dormancy was broken over time (see Table 4). The mean densities and standard errors of all cultivars for each species and year are listed in Table 4.

Table 3. Mean densities and significant differences (not including sheep fescue, α=0.05) of seeded grass species in the Shell-Pinedale Field Planting. Grasses in the species column had significantly greater densities than those listed in the statistically less dense column of the same row.

Species	Density/ft^2	Statistically less dense
Elymus lanceolatus ELLA3	2.9	KOMA, PSSP6, POSE, ELWA2, ACHY, ELTR7, ELEL5
Leymus cinereus LECI4	2.4	KOMA, POSE, ELWA2, ACHY, ELEL5
Pascopyrum smithii PASM	1.8	KOMA, POSE, ACHY, ELEL
Elymus trachycaulus ELTR7	1.6	KOMA, POSE, ACHY, ELEL
Pseudoroegneria spicata PSSP6	1.5	KOMA, POSE, ACHY, ELEL
Leymus salinus LESA4	1.2	
Elymus wawawaiensis ELWA2	0.6	
Elymus elymoides ELEL5	0.6	
Poa secunda POSE	0.3	
Achnatherum hymenoides ACHY	0.3	
Koeleria macrantha KOMA	0.1	
Festuca ovina FEOV	<0.1	Not included in the analysis

The results of the visual evaluation of stand are shown in Figure 5 and support the density count results. The ANOVA testing species effects on stand estimates breaks the species out into three groups (highest to lowest): 1. basin wildrye (5.5) and thickspike wheatgrass (5.0); 2. slender wheatgrass (3.9), bluebunch wheatgrass (3.8), western wheatgrass (3.2), and Salina wildrye (2.8); 3. bottlebrush squirreltail (2.4), Snake River wheatgrass (2.3), Sandberg bluegrass (1.8), Indian ricegrass (1.4), and prairie Junegrass (1.3). Slender wheatgrass stands were not significantly less than the two species in group 1 and Salina wildrye stands were not significantly greater than the species in group 3.

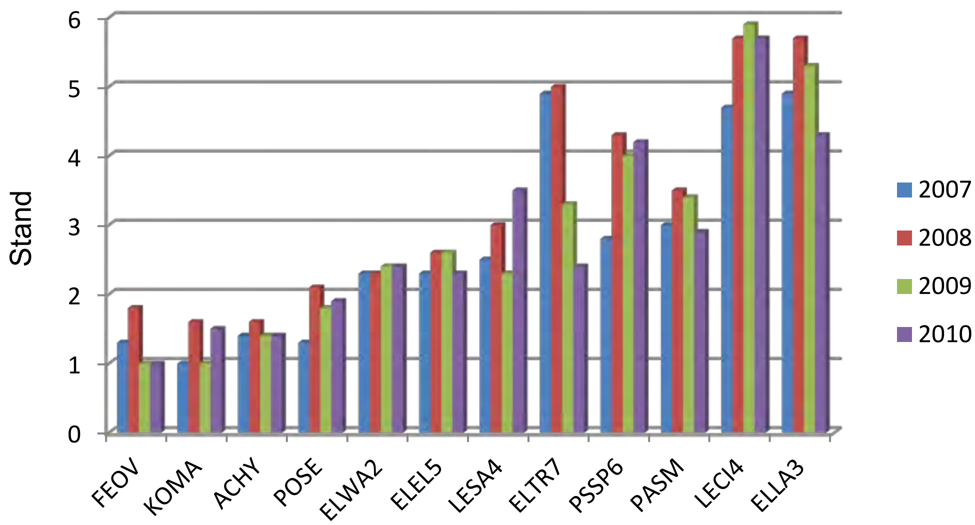

Figure 5. The mean visual stand evaluation rated from zero to nine where nine is the most even stand establishment at the Shell-Pinedale Field Planting.

Biomass

Biomass production by species by year is presented in Figure 6. It took three growing seasons under these conditions for plants to reach mature size. Not surprisingly, the ANOVA showed the amount of biomass clipped in each of the three years was significantly affected by the species planted (P<0.0001 in each year). As expected, the tall-statured basin wildrye produced the most biomass in each of the three years it was clipped. However, thickspike wheatgrass, not known for its tall stature relative to some of the other grasses, consistently produced well, in part because of its even establishment. Bluebunch wheatgrass also produced a fair amount of biomass. The results suggest these three species included in a mix will provide forage and cover for wildlife. The production of the other species was less than expected in part because of uneven stand establishment. Statistical differences among species are listed in Table 8 in Appendix A. Biomass means and standard errors of all cultivars for each species and year are listed in Table 4.

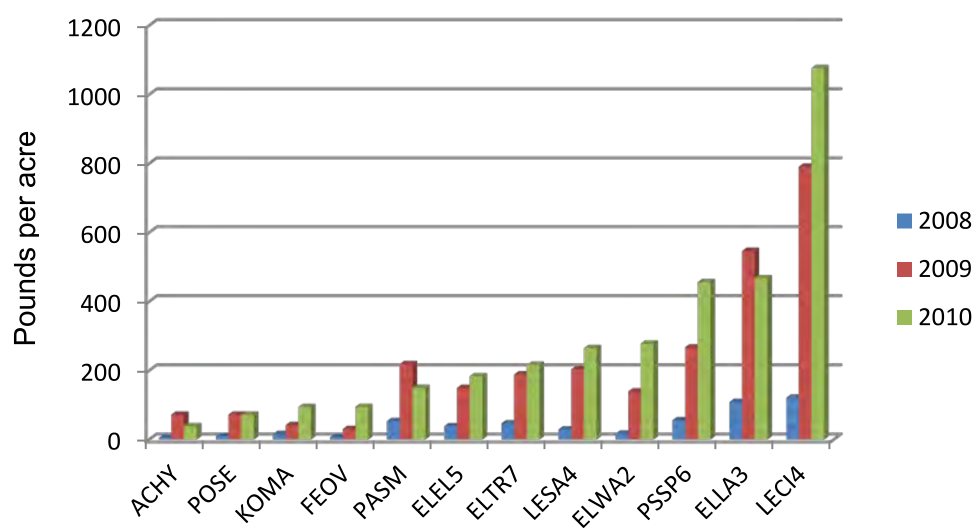

Figure 6. The mean biomass values for seeded grasses by year at the Shell-Pinedale Field Planting.

The height data (see Figure 7) show plant height was relatively consistent across all species, contrary to the biomass results. This is because few plants were sampled, the tallest ones were measured in most cases, and in most cases they were measured to the top of the inflorescences. While this is not an indication of forage production or cover, this result suggests all species, even the ones with poor establishment, had the potential to be reproductive (though no seeds were collected), which is an indication of adaptation to the site. Similar to the biomass data, it shows it took three growing seasons for the plants to reach reproductive maturity.

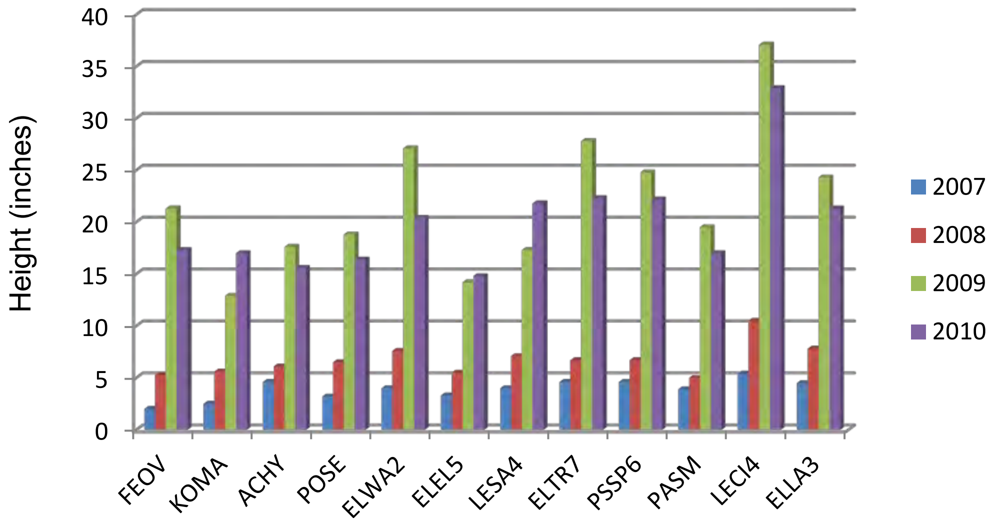

Figure 7. Plant height (inches) of the seeded grass species at the Shell-Pinedale Field Planting.

The results of the vigor evaluations in Figure 8 show, again contrary to the biomass results, the plants had similar vigor ratings regardless of the species. Even the species like sheep fescue that only established a few plants, those plants appeared as vigorous as one would expect. This together with the height results suggest they all are adapted to the site and will persist.

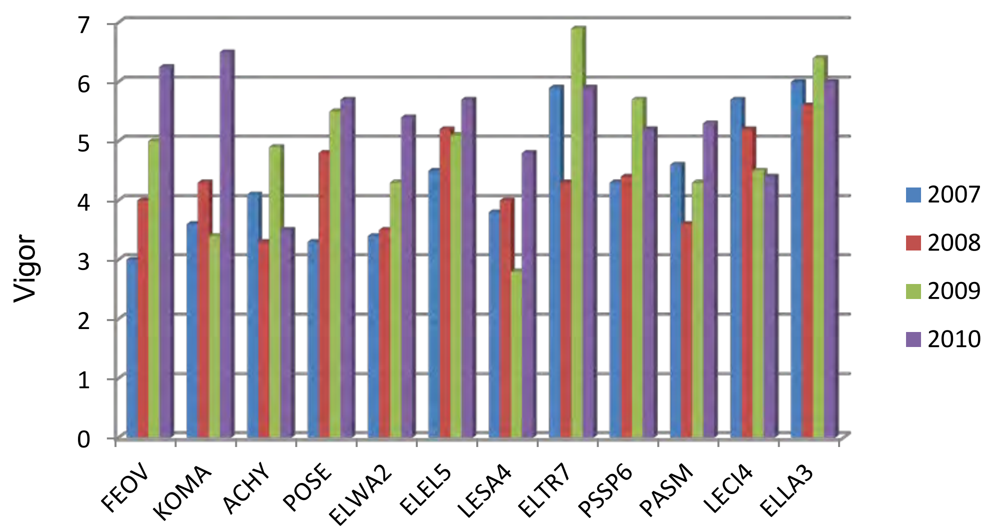

Figure 8. The visual estimate of plant vigor within the seeded grass plots at the Shell-Pinedale Field Planting.

Table 4. Means (standard errors) of density and biomass (N=4) for each grass species and accession seeded for all years evaluated on the Shell-Pinedale gas exploration well-pad Field Planting.

Species	Accession	Density Per Square Foot				Pounds per Acre		
		2007	2008	2009	2010	2008	2009	2010
ACHY	Rimrock	0.3 (0.2)	0.1 (0.1)	0.2 (0.1)	0.3 (0.1)	6 (5)	99 (43)	58 (16)
	Nezpar	0.8 (0.5)	0.1 (0.1)	0.2 (0.1)	0.3 (0.1)	3 (1)	45 (17)	19 (10)
ELEL5	Pueblo	0.7 (0.5)	0.1 (0.1)	0.0 (0.0)	0.1 (0.1)	4 (3)	52 (22)	83 (50)
	9019219	0.2 (0.3)	1.5 (0.5)	1.1 (0.2)	1.2 (0.3)	108 (33)	389 (69)	439 (69)
	Wapiti	0.4 (0.4)	0.3 (0.1)	0.3 (0.2)	0.1 (0.1)	4 (4)	6 (4)	27 (24)
ELLA3	Sodar	4.3 (0.6)	4.3 (1.0)	2.4 (0.5)	4.3 (1.4)	117 (37)	421 (109)	469 (200)
	Bannock	2.5 (0.6)	3.2 (0.9)	1.3 (0.2)	1.4 (0.5)	66 (10)	332 (55)	213 (113)
	Critana	2.5 (0.5)	3.4 (1.3)	2.6 (0.9)	2.9 (1.0)	141 (33)	886 (37)	719 (186)
ELTR7	Copperhead	3.9 (0.8)	3.0 (0.9)	0.7 (0.3)	1.0 (0.7)	64 (20)	111 (46)	92 (62)
	Pryor	2.5 (0.4)	1.0 (0.1)	0.5 (0.1)	0.4 (0.2)	39 (15)	236 (49)	272 (82)
	San Luis	2.5 (0.3)	1.8 (0.4)	0.9 (0.4)	0.6 (0.3)	34 (10)	217 (105)	283 (130)
ELWA2	Secar	0.8 (0.3)	0.8 (0.2)	0.5 (0.2)	0.6 (0.1)	22 (6)	200 (70)	426 (172)
	Expedition	0.4 (0.1)	0.4 (0.1)	0.3 (0.1)	0.3 (0.2)	11 (6)	78 (39)	130 (116)
FEOV	Covar	0.1 (0.2)	0.1 (0.2)	0.1 (0.2)	0.1 (0.5)	6 (4)	30 (16)	94 (38)
KOMA	9087539	0.1 (0.5)	0.1 (0.4)	0.1 (0.5)	0.1 (0.5)	6 (4)	55 (16)	33 (12)
LECI4	Magnar	2.3 (0.5)	1.9 (0.7)	1.1 (0.4)	0.1 (0.3)	85 (25)	661 (249)	750 (225)
	L-46	4.3 (0.9)	6.7 (1.6)	1.8 (0.2)	2.4 (0.5)	160 (24)	755 (204)	1363 (383)
	Continental	3.6 (0.3)	2.8 (1.0)	2.2 (0.7)	1.6 (0.4)	91 (33)	701 (258)	812 (386)
	Washoe	2.1 (0.6)	2.7 (0.6)	1.9 (0.3)	2.0 (0.3)	144 (42)	887 (323)	1328 (550)
	Trailhead	2.1 (1.2)	1.7 (1.0)	1.4 (0.5)	1.7 (0.4)	124 (43)	949 (339)	1129 (542)
LESA4	9043501	1.3 (0.6)	1.2 (0.7)	0.5 (0.3)	1.6 (0.5)	29 (19)	204 (62)	264 (103)
PASM	Rodan	2.0 (0.9)	1.5 (0.7)	2.5 (1.8)	2.1 (1.0)	75 (40)	247 (136)	158 (70
	Rosana	1.8 (0.3)	1.9 (0.7)	1.0 (0.3)	1.0 (0.3)	22 (13)	191 (84)	139 (45)
POSE	Opportunity	0.1 (0.1)	0.1 (0.1)	0.2 (0.1)	0.2 (0.1)	11 (6)	75 (45)	53 (24)
	High Plains	0.3 (0.3)	0.5 (0.3)	0.3 (0.2)	0.5 (0.3)	11 (6)	49 (8)	74 (31)
	Sherman	0.5 (0.2)	0.6 (0.4)	0.4 (0.1)	0.3 (0.1)	8 (4)	92 (33)	87 (47)
	9092261	0.3 (0.2)	0.4 (0.4)	0.1 (0.1)	0.2 (0.0)	3 (3)	27 (16)	154 (43)
PSSP6	Goldar	1.6 (0.5)	1.0 (0.4)	0.8 (0.2)	0.9 (0.3)	42 (14)	127 (41)	369 (118)
	P-22	1.3 (0.3)	0.8 (0.3)	0.8 (0.3)	0.5 (0.3)	21 (11)	181 (51)	320 (98)
	P-19	1.9 (0.3)	1.8 (0.3)	1.2 (0.1)	1.2 (0.3)	45 (11)	289 (46)	593 (154)
	Anatone	2.3 (0.4)	1.9 (0.3)	1.1 (0.3)	1.3 (0.3)	66 (8)	270 (81)	335 (89)
	Columbia	3.3 (0.5)	2.6 (0.4)	2.0 (0.3)	2.4 (0.7)	103 (31)	468 (162)	660 (255)

DIFFERENCES AMONG ACCESSIONS

Nine of the twelve grass species had more than one accession tested (see Table 2). Of the nine, ANOVA detected differences in density among accessions of three species; bottlebrush squirreltail, basin wildrye, and bluebunch wheatgrass. Differences in biomass among accessions of a species were also detected by ANOVA for three species, bottlebrush squirreltail, thickspike wheatgrass, and Snake River wheatgrass. Discussions of species with significantly different accessions follow, otherwise all the means and standard errors (N=4) for densities and biomasses of all accessions by species for all years are listed in Table 4 above.

Bottlebrush Squirreltail

Three accessions of bottlebrush squirreltail were planted (see Table 2). Accession 9019219 (see Figure 9) established at 1.3 plants per square foot which was greater than (P=0.0192) both Wapiti and Pueblo which had 0.3 and 0.2 plants per square foot, respectively. In 2009 and 2010, 9019219 produced 398 and 439 pounds per acre biomass, greater than (P=0.001) its production in 2008 (108) and the production in each of the three years of both Pueblo and Wapiti (46 and 12, respectively, averaged over the three years). Accession 9019219 is an experimental accession of the subspecies *E. elymoides* ssp. *elymoides*, whereas Pueblo and Wapiti are *E. elymoides* ssp. *brevifolius*, and is the reason we give for its establishment success on this site. Both Pueblo and Wapiti have established well in higher precipitation ecological sites in this region of Wyoming. These results support recommending 9019219 over Pueblo and Wapiti for reclaiming this site.

Figure 9. Accession 9019219 Bottlebrush Squirreltail in 2010.

Basin Wildrye

The densities of all basin wildrye accessions were 1.0 or greater and therefore establishment of all accessions in all years were sufficient to prevent soil erosion. The density of L-46 in 2008 (6.7 per square foot) was greater than all accessions in all years (P=0.0105) except its own density in 2007 (4.3), Magnar in 2007 (2.3), Continental in 2007 (3.6) and 2008 (2.8), and Washoe in 2008 (2.7). Averaged over all years, density of L-46 (3.8 per square foot) was no different than Continental (2.5 per square foot) or Washoe (2.2 per square foot), but was greater than (P=0.0202) Magnar and Trailhead (both 1.2 per square foot). Biomass production was not different among accessions (P=0.8115) but averaged over accessions was greater (P<0.0001) in 2010 (1,076 pounds per acre) and 2009 (791 pounds per acre) than 2008 (121 pounds per acre). Continental basin wildrye is a more recent variety selected by the Agricultural Research Service for quick establishment and strong seedling vigor, while L-46 is an experimental line. The results support recommending L-46 or Continental (see Figure 10) over Magnar and Trailhead.

Figure 10. Continental basin wildrye in 2010.

Bluebunch Wheatgrass

Five accessions (three experimental lines) of bluebunch wheatgrass were planted (see Table 2). P-24 established at the greatest density, 2.6 plants per square foot averaged over the four years which was significantly greater than Goldar (1.1 per square foot), and P-22 (0.9 per square foot) which established at the lowest density (*P*=0.0306). Densities of P-19 (1.5 per square foot), and Anatone (1.6 per square foot, see Figure 11) were not different than P-24, Goldar, or P-22. The results support recommending P-24 over Goldar and P-22.

Figure 11. Anatone bluebunch wheatgrass.

Thickspike Wheatgrass

Three accessions of thickspike wheatgrass were planted (see Table 2). Both Critana and Bannock are of the subspecies (*E. lanceolatus* ssp. *lanceolatus*) whereas Sodar is *E. lanceolatus* ssp. *riparium*. The habitat requirements for both subspecies are similar except *riparium* is more adapted to fine textured soils. Critana and Sodar readily establish on critically disturbed sites whereas Bannock prefers moderately loamy soils and is noted for its high forage production. Sodar is often recommended over Critana and Bannock on harsher sites.

The ANOVA did not detect differences in densities among the three varieties, but more Sodar stems were counted than Critana (in most years) which had more stems than Bannock (see Table 4). However, the ANOVA did detect differences among the three varieties in the amount of biomass produced (*P*=0.0546). Averaged over the three years of evaluation, Critana (see Figure 12) produced 582 pounds per acre which was greater than Bannock (204 pounds per acre). Sodar produced 336 pounds per acre, not significantly different than either Critana or Bannock. These results indicate Critana and Sodar are better choices than Bannock on this critically disturbed site.

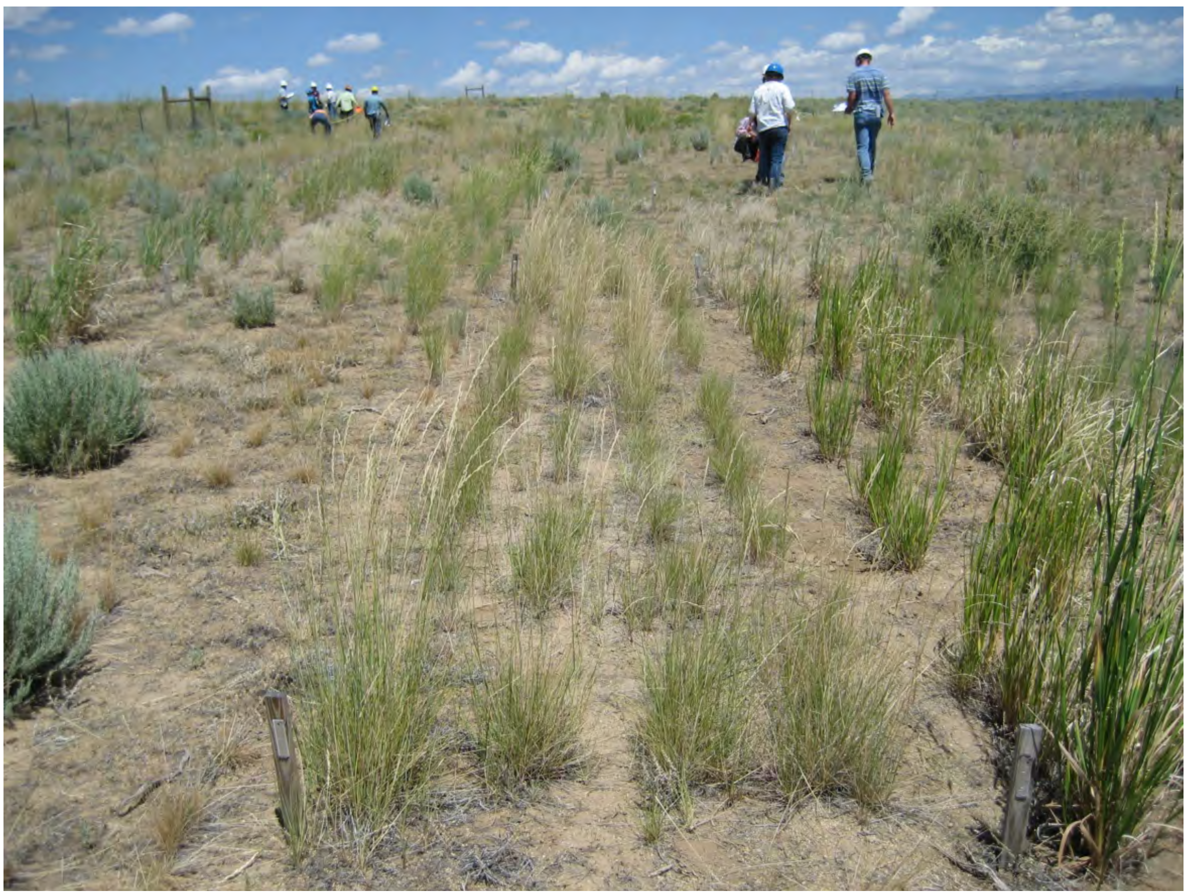

Figure 12. Critana thickspike wheatgrass.

Snake River Wheatgrass

Two accessions of Snake River wheatgrass were planted (see Table 2). Their densities did not differ significantly. But Secar (see Figure 13) produced 216 pounds per acre averaged over the three years of evaluation, significantly greater than (P=0.0595) E-45 (73 pounds per acre) supporting a recommendation for Secar if forage production is a management goal.

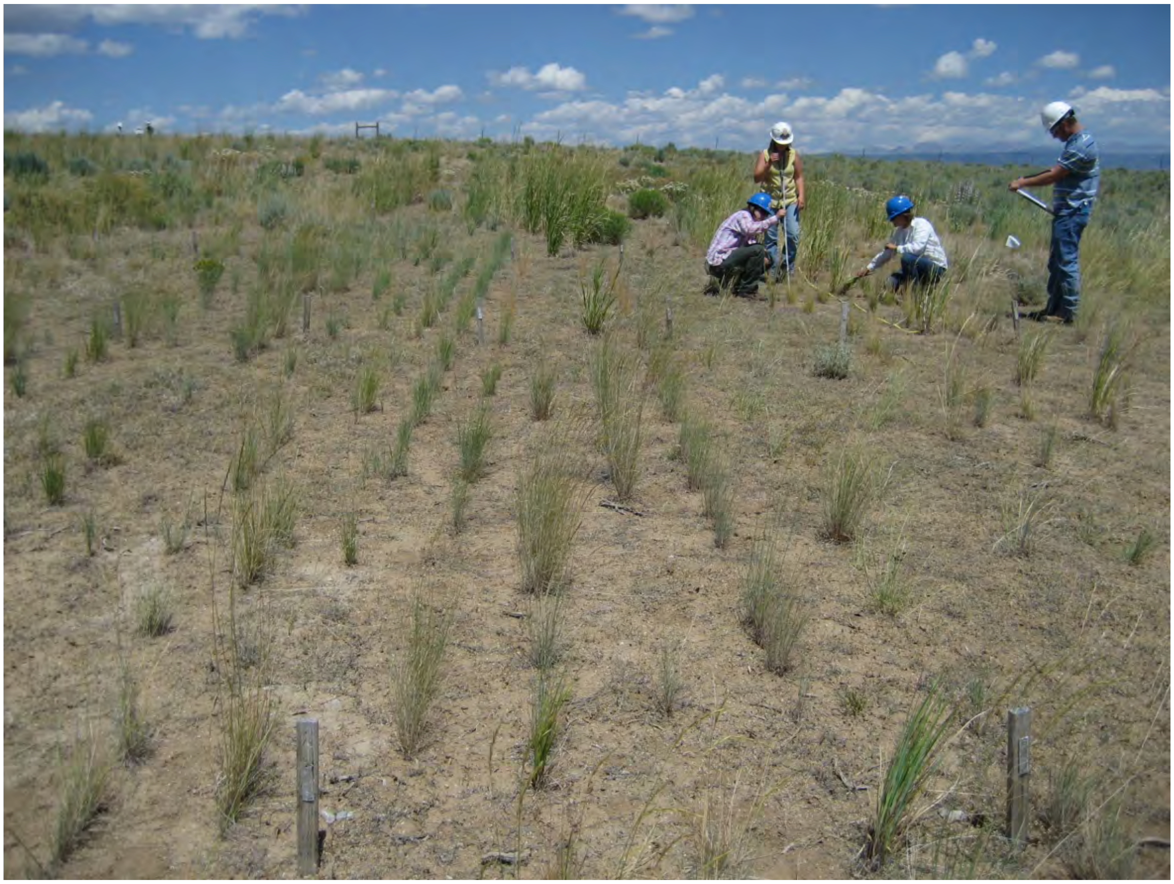

Figure 13. Secar Snake River wheatgrass.

Despite no statistically significant differences in density or biomass among the slender wheatgrass or bluegrass entries, they are important species commonly used in seed mixtures to re-vegetate many types of disturbances. The following descriptions are provided to assist land managers in selecting the most appropriate plant material for their needs.

Slender Wheatgrass

Three accessions of slender wheatgrass were planted (see Table 2). Pryor is most recommended for stabilizing disturbed sites in semi-arid environments above 3,500 feet with 10 or more inches of precipitation. It is very tolerant of drought and saline conditions. San Luis is most recommended for stabilizing slopes and disturbed sites above 6,000 feet with 14 or more inches of precipitation. Copperhead is most recommended for stabilizing severely impacted mining and smelting sites with low pH and high concentrations of heavy metals above 4,000 feet with 13 or more inches of precipitation. Slender wheatgrass is short-lived (three to five years), establishes quickly, and produces abundant forage and seed.

Figure 14. Pryor slender wheatgrass.

Bluegrass

Three accessions of bluegrass were planted (see Table 2). These three entries are currently lumped taxonomically in the Sandberg bluegrass complex (*Poa secunda)*, however, their original nomenclature, phenotypic forms, and habitat preferences are quite different.

Sherman big bluegrass (synonym *Poa ampla*) is large-statured (often exceeding three feet tall), and most recommended for stabilizing disturbances on well-drained sites in areas receiving nine to 20 inches of precipitation annually. It has performed well in re-vegetation of open aspen and conifer forests and mountain brush communities. Sherman has been used extensively to reseed burned-over forest lands. Big bluegrass occurs naturally on upland sites in open lodgepole and ponderosa pine forests. It is intolerant of saline, alkaline, or heavily-timbered conditions. Big bluegrass greens up very early in the spring and produces an abundant amount of palatable forage for many game animals and all classes of livestock.

Figure 15. Sherman big bluegrass in the front center plot.

Opportunity Germplasm Nevada bluegrass (synonym *Poa nevadensis*) grows to a height of two feet tall. It originates from an acidic site (pH 4.3) severely contaminated with heavy metals deposited from smelter fallout near Anaconda, Montana. Opportunity is most recommended for mine land reclamation, as well as reseeding rangeland and abandoned logging roads. It is tolerant to moderately alkaline soils. Nevada bluegrass prefers to grow in moist, open areas of mountain foothills and in the upper reaches of riparian areas, but can be found in dry open meadows and hillsides. It is rarely abundant, but where present, produces a moderate amount of nutritious forage and seed.

High Plains Germplasm Sandberg bluegrass (synonym *Poa sandbergii*, see Figure 16*)* is small-statured (eight to 14 inches tall) and is most recommended for re-vegetating disturbances in medium-textured soils on badlands, ridge tops, and dry, stony, or sandy soils. Sandberg bluegrass is one of the first grasses to green up in the spring, and is drought-resistant, tolerant of grazing, and withstands trampling. It produces a small amount of forage that is palatable to livestock and wildlife. Sandberg bluegrass is a pioneer species and will easily colonize on disturbed sites.

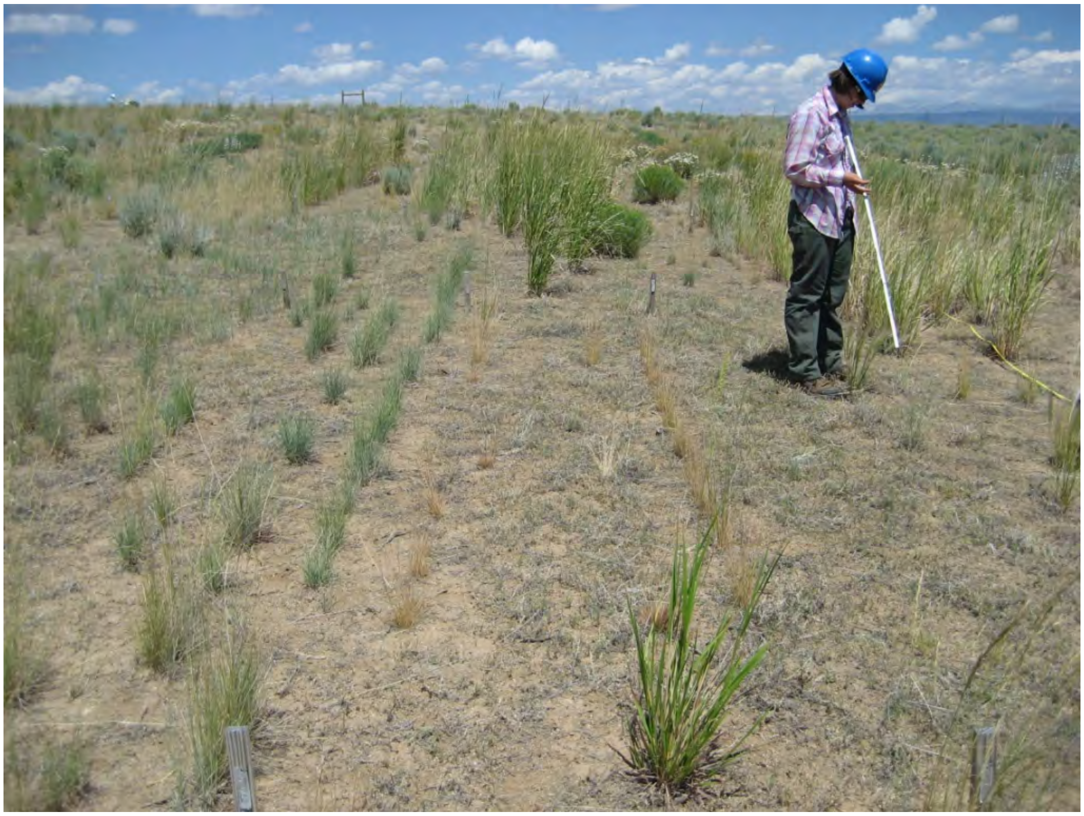

Figure 16. Small plants (brown) of High Plains Sandberg bluegrass.

CONCLUSIONS

The results of this field planting show native grass species establish at different rates on this site. Under hotter and drier than normal conditions during the first two establishment years, and based on probabilities, thickspike wheatgrass, basin wildrye, western wheatgrass, slender wheatgrass, and bluebunch wheatgrass have better chances of establishing a stand that functions to stabilize the soil and support wildlife habitat than most of the other species tested on this site.

The results also show differences in density and biomass among accessions of some species suggesting they will establish or function differently. Under hotter and drier than normal conditions during the first two establishment years, and based on probabilities, accession 9019219 bottlebrush squirreltail, L-46 basin wildrye, P-24 bluebunch wheatgrass, Critana thickspike wheatgrass, and Secar Snake River wheatgrass are expected to perform better than other accessions or cultivars of these species.

Figure 17. On-site gas well maintenance eight years after drilling and five years after reclamation.

Acknowledgements

This field planting was a cooperative effort of Shell Exploration and Production Company (Shell), USDI-Bureau of Land Management (BLM), Wyoming Game and Fish Department (WGFD), the USDA-Natural Resources Conservation Service (NRCS), and the Sublette County Conservation District (SCCD). All entities provided staff and equipment to put this project on the ground.

We would especially like to thank: Aimee Davison, Shell; Dan Stroud, WGFD; Dessa Dale, BLM; Jill Randall, WGFD; Larry Holzworth, NRCS; and Jennifer Hayward, NRCS for making this project possible through their dedication and hard work from project conception to implementation.

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Seed was provided by the Bridger Plant Materials Center, Upper Colorado Environmental Plant Center, Shell, Aberdeen Plant Materials Center, Bismarck Plant Materials Center, Pullman Plant Materials Center, and the USDA-Agriculture Research Service (ARS).

Appendix A

Statistical Analysis

To test the hypothesis that native grass establishment is affected by the species planted and the year sampled we used a split-plot in time analysis of variance (ANOVA) model with accessions (where more than one accession per species were planted) pooled within species as the whole-plot independent variable and year as the sub-plot independent variable. The species by year interaction was included in the model. The six density sub-samples were averaged and the average was used as the dependent variable in the density ANOVA model. Covar sheep fescue established very few plants, was considered an outlier in the dataset and not included in the model. This and a square root transformation were used to meet assumptions of ANOVA. This model was also used for vigor, stand and height evaluations, but only the stand data met the assumptions of ANOVA. The *P*-values for the density and stand ANOVAs are shown in Table 5.

Table 5. The *P*-values from the ANOVA testing for significant species, year, and their interaction effects on densities and stand.

Source	DF	Density	Stand
Replication	3		
Species	10	0.0000	0.0000
Rep*spp (error)	30		
Year	3	0.0000	0.0790
Species*year	30	0.0734	0.1977

The split-plot model described for density was used to test species, year and their interaction effects on biomass but did not meet assumptions of ANOVA. It indicated year significantly affected biomass production. Therefore, a randomized complete block model with accessions pooled within species as the independent variable was run for each year to test species effects on biomass production. Sheep fescue was removed as an outlier and data from each year were square root transformed to meet ANOVA assumptions. The *P*-values for the species variable each year are <0.0001.

Figure 18. A crew counts the density and measures the height of basin wildrye.

To test the hypothesis that there were differences among accessions of a species, a split-plot model was run for each of the nine species with more than one accession. In the model, accession was the whole-plot independent variable, year was the sub-plot independent variable, and the accession by year interaction was included. The model was run for density and biomass dependent variables. Data were square root transformed when needed to meet the assumptions of ANOVA. The *P*-values for density are shown in Table 6 and the *P*-values for biomass are shown in Table 7.

Table 6. The *P*-values from the ANOVAs testing for accession, year, and their interaction on densities by species.

Source	DF	ACHY	ELEL5	ELLA3	ELTR7	ELWA2	LECI4	PASM	POSE	PSSP6
Rep	3									
Accession	3	0.7566	0.0192	0.3008	0.1833	0.6060	0.0202	0.6985	0.6683	0.0049
Rep*acc (error)	9									
Year	3	0.1099	0.3312	0.0536	0.0000	0.0485	0.0000	0.9685	0.0743	0.0000
Acc*year	9	0.3610	0.3394	0.6107	0.1753	0.3337	0.0105	0.4641	0.2260	0.9724

Table 7. The *P*-values from the ANOVAs testing for accession, year, and their interaction on biomass by species.

Source	DF	ACHY	ELEL5	ELLA3	ELTR7	ELWA2	LECI4	PASM	POSE	PSSP6
Rep	3									
Accession	3	0.1397	0.0018	0.0546	0.4583	0.0595	0.8151	0.6903	0.9063	0.3202
Rep*acc (error)	9									
Year	3	0.0051	0.0001	0.0000	0.0022	0.0158	0.0000	0.0346	0.0001	0.0000
Acc*year	9	0.3084	0.0010	0.0514	0.2663	0.2075	0.9144	0.9388	0.0548	0.3878

Tukey's means separation ($\alpha=0.05$) were used to determine differences among species or accessions when the F-test was significant ($P<0.05$ in most cases). For all results, actual values and not square root transformed values are presented.

Table 8. The mean biomass production (lb./ac.) by species from at the Shell-Pinedale Field Planting from 2008 to 2010. Different letters after the mean values indicate statistical differences among species within that year determined by ANOVA and Tukey's mean separations (α=0.05). Sheep fescue was not included in the ANOVA model (asterisk).

Species	2008	2009	2010
Basin wildrye	121 a	791 a	1076 a
Thickspike wheatgrass	108 ab	546 ab	467 b
Bluebunch wheatgrass	56 b	276 bc	456 b
Snake River wheatgrass	17 bc	139 cd	278 bc
Saline wildrye	27 bc	203 bcd	264 abc
Slender wheatgrass	46 bc	188 cd	216 bc
Bottlebrush squirreltail	38 c	149 cd	183 bc
Western wheatgrass	48 bc	219 bcd	149 bc
Sandberg bluegrass	8 c	61 d	92 c
Indian ricegrass	4 c	72 cd	39 c
Prairie Junegrass	6 c	55 cd	33 c
Sheep fescue	6 *	30 *	94 *