Influence of Sagebrush and Grass Seeding Rates on Sagebrush Density and Plant Size

Laurel E. Vicklund
Gerald E. Schuman
Ann L. Hild

Abstract: Wyoming big sagebrush (Artemisia tridentata ssp. wyomingensis) establishment on mined lands in Wyoming is a critical element of reclamation success. Because of its importance to wildlife, shrub density is used to assess reclamation success for wildlife habitat in Wyoming. Research was initiated at the Belle Ayr Mine near Gillette in 1999 to evaluate the effects of Wyoming big sagebrush seeding rates and grass competition on sagebrush establishment. Sagebrush seedling densities demonstrated consistent increases with increased sagebrush seeding rates. The 4 kg PLS per ha sagebrush seeding rate resulted in significantly greater density than either the 2 or 1 kg PLS per ha seeding rate in 1999 to 2001. Grass competition (grass seeding rates of 0, 2, 4, 6, 8, 10, and 14 kg PLS per ha of a mixture of C3 native species) did not significantly affect sagebrush seedling density. However, 1999 and 2000 precipitation was above or near normal, resulting in adequate moisture for seedling emergence and growth of all seeded species. Sagebrush seedling density declined at the higher grass seeding rates in 2001, but seedling density was not significantly affected by grass seeding rates (P = 0.12). Precipitation in 2001 was well below normal, and grass competition significantly affected sagebrush seedling canopy volume. Sagebrush seedling canopies were significantly smaller at grass seeding rates greater than or equal to 4 kg PLS per ha. Continued evaluation of these treatments on sagebrush seedling performance will enable development of a seeding strategy that enhances establishment of Wyoming big sagebrush on reclaimed mine lands.

Methods

The study site was located at the RAG Coal West, Inc., Belle Ayr Mine, 29 km southeast of Gillette, WY. Climate at the site is continental, elevation is 1,460 m, mean air temperature is 6.7 °C and the average annual precipitation is 376 mm (Belle Ayr Coal Mine 2001). The premine vegetation of the area is a northern mixed-grass prairie primarily comprised of cool- and warm-season grasses and Wyoming big sagebrush. Soils are derived from Tertiary and Upper Cretaceous shale, limestone, and sandstone. The topsoil was a sandy clay loam, with a pH of 7.6, EC of 2.0 dS per m, total nitrogen concentration of 700 mg per kg, and a soil organic carbon content of 1.0 percent.

Topsoil replacement (56 cm) was completed in December 1997 to January 1998, and the area was seeded to barley (Hordeum vulgare var. "Steptoe") in April 1998 to establish a stubble mulch. In December 1998, seven grass seeding rates treatments (0, 2, 4, 6, 8, 10, and 14 kg PLS [pure live seed] per ha) were randomly drilled into 6.5 by 27 m main plots within each of four replicate blocks. The grass mixture (approximately equal seed numbers of each species) was...
composed of three cool-season native perennials: western wheatgrass (*Pascopyrum smithii* [Rydb.] A. Love), thickspike wheatgrass (*Elymus lanceolatus* [Scribner & J. G. Smith] Gould), and slender wheatgrass (*Elymus trachycaulus* [Link] Gould ex Shinners). Each grass seeding treatment plot was subdivided into three, 6- by 9-m plots, which were randomly seeded to one of three Wyoming big sagebrush seeding rates (1, 2, or 4 kg PLS per ha) in March 1999.

Six 1-m² quadrats were permanently marked in each sagebrush seeding rate subplot in early 1999 before seeding emergence. Sagebrush seedlings were counted within each of these quadrats on June 30, August 3, August 31, and October 25, 1999; June 5 and September 18, 2000; and June 20 and September 27, 2001. In 1999, a high density of colonizing forb species (*Kochia scoparia*, *Melilotus officinalis*, *Salsola kali*) were present on the site. To mimic reclamation practices and to aid in the counting of sagebrush seedlings, the plots were mowed at about 15 to 18 cm in height and the material removed from the plots. In July 2000 and 2001 herbaceous plant biomass at peak standing crop was determined by clipping four 0.18-m² quadrats within each of the 84 sagebrush by grass seeding rate subplots. Aboveground biomass was separated into planted grasses, exotic grasses (*Bromus japonicus*, *B. tectorum*, *E. junceus*), and forbs. Volunteer barley from the stubble mulch was included with the exotic grasses but comprised a very small portion of the total biomass.

In 2001, sagebrush seedling volume was estimated on all of the seedlings counted within the permanent quadrats. This parameter was included because of the visual perception of differences in sagebrush seedling size among grass seeding rates. Sagebrush seedling volume was determined by using a caliper to measure the plant canopy diameter at its widest point, crown diameter perpendicular to the first measurement, and the plant height. Plant volume was calculated with the assumption that plant shape most closely resembled an ellipse cone.

Analysis of variance was conducted on plant biomass, sagebrush seedling density, and sagebrush seedling volume using a split-split plot randomized block design (SAS Institute 1999). Mean separation was accomplished using Fisher’s protected least significant difference procedures. All statistical analyses were evaluated at $P < 0.05$.

**Results and Discussion**

Sagebrush seedling density data (1999 and 2000) and aboveground plant biomass data (2000) were reported earlier by Williams and others (2002) but will be included in this paper to demonstrate longer term trends and responses over a wider range of climatic conditions. Precipitation in 2001 was considerably less than in 1999 and 2000, which were near-normal or above-normal precipitation years (fig. 1).

**Grass Seeding Rate Responses**

Biomass of planted grasses in 2000 and 2001 showed similar trends (fig. 2). In 2000, aboveground biomass of planted grasses was significantly lower for grass seeding rates of 0 and 2 kg PLS per ha and did not differ among grass seeding rates of greater than or equal to 4 kg PLS per ha. In 2001, planted grass aboveground biomass did not differ among grass seeding rates greater than or equal to 2 kg PLS per ha. These data indicate that grass seeding rates of 2 to 14 kg PLS per ha can produce similar aboveground production in the second and third year after establishment. Therefore, grass seeding rates could be lowered considerably from rates typically used by mine reclamation specialists and still achieve the mandated production standards (equal to or greater than premine). Reducing grass seeding rates could aid natural recruitment of native grass, forb, and shrub species that are less competitive (Fortier 2000; Stevenson and others 1995). Because the grass species planted in this...
study were a mixture of bunchgrass and rhizomatous species, soil protection was adequate to ensure soil stability.

Sagebrush seedling density after three growing seasons was not significantly different among grass seeding rates (fig. 3), although sagebrush seedling density within the 14 kg PLS per ha grass seeding rate was less than half that observed at the lower grass seeding rates. Grass seeding rate did not affect sagebrush seedling density even though precipitation (221 mm) in 2001 was below the long-term average (336 mm) for the site. Therefore, it appears that sagebrush seedling density did not respond to grass competition in the first 3 years of the study.

Aboveground sagebrush seedling size (canopy volume) differed among the grass seeding rates (fig. 4). Canopy volume of sagebrush seedlings was significantly smaller at grass seeding rates of greater than or equal to 4 kg PLS per ha than at the 0 and 2 kg PLS per ha grass seeding rate. No differences in sagebrush seedling volume were observed for grass seeding rates of 4 to 14 kg PLS per ha.

**Sagebrush Seeding Rate Responses**

Sagebrush seedling densities differed among the three sagebrush seeding rates within each sampling date. Sagebrush seedling density for all three seeding rates was greatest on the June 2000 count and generally declined throughout the growing season due to seedling mortality (fig. 5). In both years (2000 and 2001) sagebrush seedling density was greater with increased sagebrush seeding rate. Highest densities occurred at the 4 kg PLS per ha seeding rate. Even the 1 kg PLS per ha seeding rate resulted in sagebrush seedling densities greater than the 1 seedling per m² shrub standard. However, considering the long-term survival for big sagebrush reported by Kiger and others (1987) and Schuman and Belden (2002), seedling densities observed at the 1 kg PLS per ha seeding rate in our study would not meet the shrub standard after years 9 and 10, when the standard is assessed. Kiger and others (1987) reported survival rates of 28 to 32 percent after 11 years on a volunteer stand at a coal mine in northwestern Colorado (believed to be mountain big sagebrush, *Artemisia tridentata* ssp. *vaseyana*). However, Schuman and Belden (2002) reported a 59 percent average survival rate across several cultural treatments after 8 years in the Powder River Basin of Wyoming in a Wyoming big sagebrush stand seeded at 2.2 kg PLS per ha.

**Summary and Conclusions**

Based on the observed sagebrush seedling densities as affected by grass seeding rate it would be difficult to make
Influence of Sagebrush and Grass Seeding Rates on Sagebrush Density and Plant Size

Vickland, Schuman, and Hild

foolproof recommendations for a grass seeding rate that would provide a sagebrush density that meets the shrub standard after 10 years. However, if one assesses the effect of the grass seeding rate on sagebrush seeding density and canopy growth in the context of the sagebrush seeding rates and planted grass aboveground biomass, we suggest that sagebrush seeding rate of 2 kg PLS per ha and a grass seeding rate of 4 kg PLS per ha will likely meet management goals on comparable sites. This recommendation is based on the lack of differences in planted grass aboveground biomass in the 6 to 14 kg PLS per ha grass seeding rates, while grass seeding rates greater than or equal to 4 kg PLS per ha greatly reduced canopy size of the sagebrush seedlings. Early results indicate a trend (nonsignificant) of fewer sagebrush seedlings above the 6 kg PLS per ha grass seeding rate in 2001. We know that as grass seeding rates increase, natural recruitment and establishment of difficult-to-establish native species are significantly reduced, particularly desired forbs and shrubs (Bergelson and Perry 1989; Eissenstat and Caldwell 1988; Richardson and others 1986). We believe this recommendation should result in adequate cover, provide adequate forage production, reduce vegetative competition, and enable establishment of Wyoming big sagebrush to meet the shrub density standard required for successful mine reclamation.

Acknowledgments

We would like to thank Mary (Fortier) Williams, Rich Vincent, and Darrell Ueckert for their review of this paper. We also acknowledge the assistance of Mary Williams, Matt Mortenson, Cliff Bowen, Kristene Partlow, Jennifer (Boyle) Muscha, Leah Burgess, Krissie Peterson, Larry Griffith, Pam Freeman, Ernie Taylor, Doug Miyamoto, Kelli Sutphin, and Wes Brown and other technical support staff for help in collecting the field data. We acknowledge support of RAG Coal West, Inc., Belle Ayr Mine, Gillette, WY; the USDA ARS High Plains Grasslands Research Station, Cheyenne, WY; and the Department of Renewable Resources, University of Wyoming. This research was supported in part by the Wyoming Abandoned Coal Mine Land Research Program, administered by the Office of Research, University of Wyoming, and the Abandoned Mine Land Division, Wyoming Department of Environmental Quality, Cheyenne.

References

Belle Ayr Coal Mine. 2001. Belle Ayr mine annual report. RAG Coal West, Inc., Gillette, WY.
Soil Components and Microsites

Eriogonum exilfolium