

# EFFECTS OF WYOMING BIG SAGEBRUSH SEEDING RATE AND GRASS COMPETITION ON LONG-TERM DENSITY AND CANOPY VOLUME OF BIG SAGEBRUSH AND WILDLIFE HABITAT<sup>1</sup>

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**Abstract:** This research was initiated in 1997 to evaluate the effects of seeding rates of grass and Wyoming big sagebrush on the establishment of big sagebrush. The research was accomplished at the Belle Ayr West mine, south of Gillette, WY using a randomized complete block with three big sagebrush seeding rates (1, 2, and 4 kg PLS /ha) and seven grass seeding rates (0, 2, 4, 6, 8, 10, and 14 kg PLS /ha ) experimental design. Field data were collected from 1997-2004 and resampled in 2010 to evaluate the long-term effects of these seeding rate treatments on big sagebrush density and plant canopy volume. Wyoming big sagebrush average density decreased by 25-33% from 2004 to 2010 but the density remained above the 1 plant/m<sup>2</sup> level required by the Wyoming Department of Environmental Quality shrub density standard. Wyoming big sagebrush canopy volume in 2010 (per plant) is as much as 50 times greater than observed in 2004. When expressed on an area basis (cm<sup>3</sup>/ m<sup>2</sup>), canopy volume is about 15 times greater than measured in 2004. Grass competition did not have a significant effect, on an area basis, on canopy volume in 2010 even though it continues to influence big sagebrush density. However, we believe it remains important to consider the effects of grass competition and shrub seeding rates to ensure desired shrub densities on reclaimed mined lands in the Western U.S. Therefore, we recommend grass seeding rates of 6-8 kg pls/ha and Wyoming big sagebrush seeding rates of 2-4 kg pls/ha to ensure desired reclamation that meets regulatory requirements and provides good revegetation, forage productivity and wildlife habitat. Shrub density and cover in this study meet the guidelines for the dominant wildlife species in the region after 13 years.

**Additional Key Words:** shrub establishment, mined land reclamation, semi-arid region, shrub cover.

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## Introduction

The goal of coal mine land reclamation in the western United States is to develop a plant community that provides soil stability, wildlife habitat, and livestock grazing. Although concurrent planting of grasses, forbs, and shrubs is a common reclamation practice, this approach has often resulted in inadequate shrub establishment due to competition from herbaceous species (Blaisdell 1949; Shaw and Monsen 1988; Schuman et al. 1998). In general, high grass seeding rates create dense stands of big sagebrush with low vigor (DePuit et al. 1980) and can limit seedling emergence due to inter- and intraspecific competition (Bergelson and Perry 1989). Studies in the 1980's and 1998 showed that grass can limit *Artemisia tridentata* Nutt. ssp. *wyomingensis* (Beetle and Young), Wyoming big sagebrush (Eissenstat and Caldwell 1988; Schuman et al. 1998) and *Artemisia tridentata* ssp. *vaseyana* (mountain big sagebrush) seedling establishment (Richardson et al. 1986).

Shrub standards for reclaimed coal mine lands in Wyoming require a minimum of 1 shrub/m<sup>2</sup> on lands where the post-mine land use included wildlife habitat (Wyoming Department of Environmental Quality 1996). Even though past research has shown that competition from herbaceous species influences Wyoming big sagebrush establishments, the regulations require soil stabilization using a permanent vegetative cover as productive as pre-mine conditions and that meets pre-mine land uses. These regulatory requirements result in potential limitations to successful establishment of the desired diverse plant community. Studies by Schuman et al. (1998) and Stahl et al. (1998) have provided improved cultural techniques for sagebrush reestablishment on coal mined lands. In general, minimizing grass seeding rates may reduce losses of big sagebrush (Kleinman 1996).

This study was initiated in late 1997 to evaluate the establishment of Wyoming big sagebrush when sown with a mixture of cool-season perennial grass species on reclaimed lands at the Belle Ayr Coal mine near Gillette, Wyoming. Three sagebrush seeding rates and seven grass seeding rates were used to evaluate the influence of grass competition on sagebrush seedling establishment. The early phases (1997-2000) of this research set out to evaluate (1) whether grass seeding rate (competition) influenced Wyoming big sagebrush establishment? (2) Did Wyoming big sagebrush seeding rates influence big sagebrush seedling establishment and density? (3) Is there an interaction between grass seeding rates and Wyoming big sagebrush

seeding rates? These findings were summarized by Williams et al. (2002). Later phases of the research (2002-2010) concentrated on evaluating the effects of grass seeding rates and big sagebrush seeding rates on the canopy size and density of the Wyoming big sagebrush plants. These plant traits/characteristics are very important for wildlife habitat; especially sage grouse (*Centrocercus urophasianus*) which are presently being evaluated for protective status under the Endangered Species Act.

## **Methods and Materials**

### **Site Description**

The study site was located on the Belle Ayr Coal mine, Alpha Coal West, Inc. about 29 km southeast of Gillette, Wyoming. The Belle Ayr mine is situated in the Powder River Basin (44° 17'N, 105° 30' West) at an elevation of 1460 m and has a continental climate. Pre-mining vegetation of the Powder River Basin include localized concentrations of shrubs in a matrix of cool- and warm-season perennial grasses typical of the northern mixed grass prairie (Glasse et al. 1955). Wyoming big sagebrush is common on shallow and upland soils whereas silver sage (*Artemisia cana*) is commonly found within drainages. Soils formed from both Tertiary and Upper Cretaceous shale, sandstone, and limestone.

### **Experimental Design**

Topsoil was spread 56-cm deep from a 7-year old topsoil stockpile over 70 cm of graded, good quality spoil from December 1997 through January 1998. See Williams et al. 2002 for details of the soil properties. In the spring of 1998, the site was seeded to barley (*Hordeum vulgare* var. Steptoe). The barley was mowed in late summer and early fall of 1998 to provide a standing stubble mulch for seeding the permanent plant community. Seven grass seeding rate treatments of 0, 2, 4, 6, 8, 10, and 14 kg pure live seed (pls)/ha were randomly assigned to 6.5 by 27 m main plots within each of four 27 by 45.5 m replicate blocks. Grass seeding treatments were drill seeded into the barley stubble in December 1998, using a double disk drill at 1.5-2.0 cm depth. Three cool-season perennial grass species were used in the mix: *Pascopyrum smithii* (Rydb.) A. Love, “Barton” (western wheatgrass), *Elymus lanceolatus* (Scribner & J.G. Smith) Gould, “Critana” (thickspike wheatgrass), and *Elymus trachycaulus* (Link) Gould ex Shinners, “Pryor” (slender wheatgrass). The mix was comprised of equal numbers of seeds of each of the species which are dominant species on pre-mine lands in northeastern Wyoming.

Each grass treatment plot was divided into three, 6 by 9 m subplots, which were randomly seeded to 1, 2, or 4 kg pls/ha of Wyoming big sagebrush in March 1999. Sagebrush was broadcast seeded using a precision broadcast seeder (Hege 33 Fertilizer Distributor System, Wintersteiger USA, Salt Lake City, UT). Seeding rates between 2.2 and 3.9 kg pls/ha have proven successful for establishing Wyoming big sagebrush (Gores 1995; Quinney et al. 1996).

The experimental design was a split-plot randomized complete block design and data analysis was made using that design (Proc GLM, SAS Institute 1999). Grass seeding rate treatments were the main plots and sagebrush seeding rate treatments were the split-plot.

### Vegetation Measurements

Before seedling emergence in 1999 six 1-m<sup>2</sup> quadrates were permanently marked within each treatment combination subplot. These 1-m<sup>2</sup> quadrats were used to assess sagebrush plant density in 1999 and 2000 (Williams et al. 2002). The quadrats were also used to assess big sagebrush density and canopy volume in 2001, 2002, and 2004. To assess the long-term effects of these treatments on sagebrush density, canopy volume and cover; canopy volume and sagebrush density were assessed in May 2010 utilizing the same methods used in earlier years. These data would enable us to assess the long-term impacts/influence of grass and sagebrush seeding rates on sagebrush density and cover as it relates to wildlife habitat needs. Sagebrush density was assessed within all six 1-m<sup>2</sup> quadrats in each subplot and canopy volume was assessed on quadrat 1, 3, and 5 in each of the subplots. Canopy volume was determined by measuring the widest canopy width, the plant width perpendicular to the first measurement and plant height. Canopy volume was calculated for each sagebrush plant using the formula for an elliptical cone and volume was also totaled for each plot to obtain values per m<sup>2</sup>. Canopy volume of individual sagebrush plants is important to assess community structural development. Sagebrush seedling survival was also calculated with each treatment subplot by dividing the sagebrush densities in August 2004 and May 2010 by the initial big sagebrush seedling density measured in June 1999. To assess percent cover of the Wyoming big sagebrush we used the two horizontal measurements of each sagebrush plant to determine a cover factor (m<sup>2</sup>/plant) and calculated the percent cover for each meter quadrat measured.

## Results and Discussion

This paper will discuss the long-term survival and growth of the Wyoming big sagebrush as influenced by grass seeding rates and Wyoming big sagebrush seeding rates. The 2004 data will be used to compare to the 2010 findings. Further detail of the 2000, 2001, and 2004 findings can be found in Hild et al. 2006.

### Sagebrush density

Sagebrush plant densities did not differ significantly in 2010 as a result of grass seeding rates which was true throughout the study period. Sagebrush plant densities were variable within grass seeding rates which accounted for the lack of significant differences. However, the highest grass seeding rate, 14 kg pls/ha resulted in about 50% reduction in sagebrush density compared to the 0 kg pls/ha grass seeding rate, both in 2004 and 2010, Fig. 1. The mean big sagebrush plant densities in 2004 and 2010 are 3.0 and 2.2 plants/m<sup>2</sup>, respectively, across all grass seeding rates, which is well above the Wyoming regulation of 1 plant/m<sup>2</sup>. Sagebrush plant density

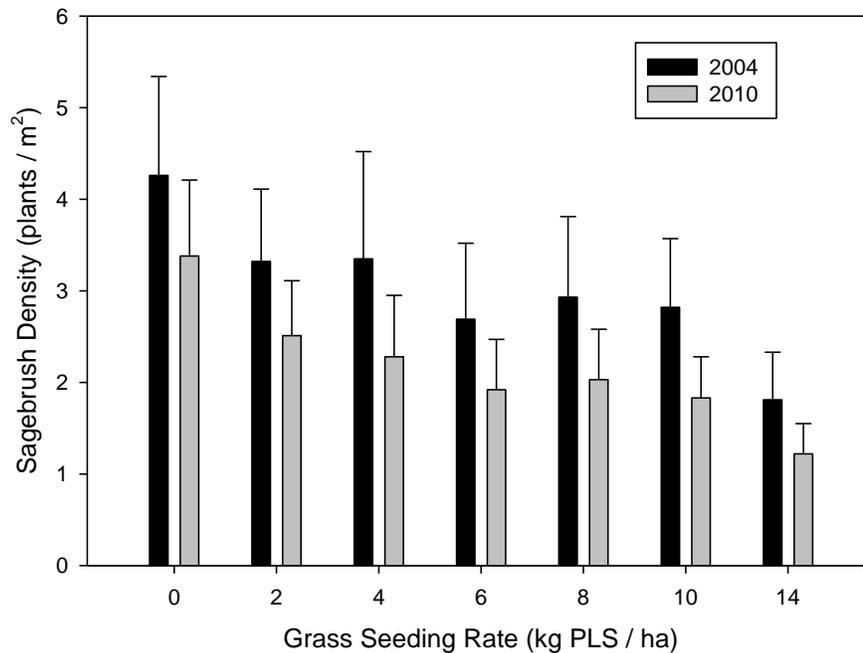


Figure 1. The effects of grass seeding rate on Wyoming big sagebrush density, Belle Ayr Mine, Gillette, WY, 2004 and 2010.

was significantly greater as sagebrush seeding rate increased, Fig. 2. The mean big sagebrush plant density across all treatments decreased by an average of 30% from 2004 to 2010.

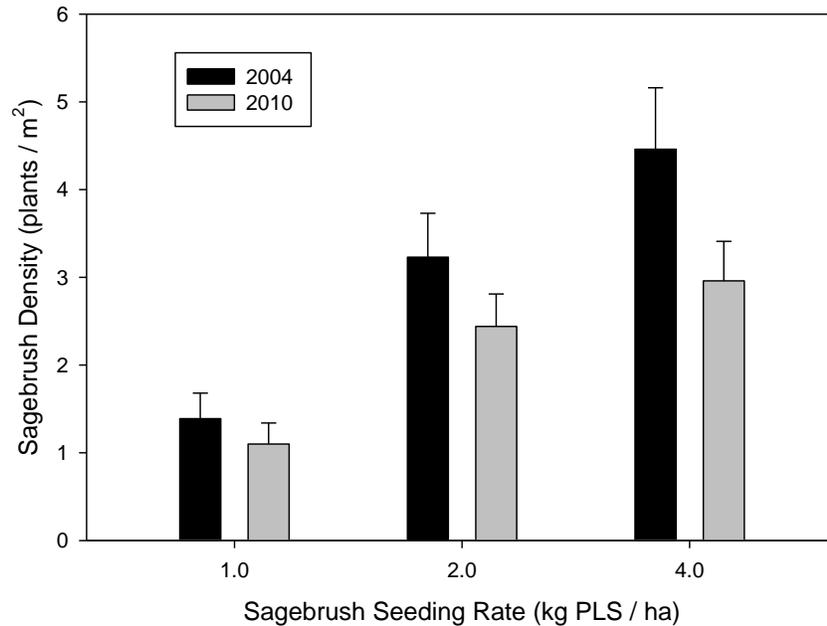


Figure 2. The effect of Wyoming big sagebrush seeding rate on sagebrush density, Belle Ayr Mine, Gillette, WY, 2004 and 2010.

### Canopy Volume of sagebrush

Canopy volume per plant was quite variable in both 2004 and 2010, Fig. 3. However, in 2004 canopy volume per plant (cm<sup>3</sup>) was significantly higher at the 0 and 4 kg pls/ha grass seeding rates. In 2010 the greatest canopy volume observed occurred at the 14 kg pls/ha grass seeding rate. This might be explained by the fact that this grass seeding rate produced the lowest sagebrush plant density therefore the canopy volume per plant was the highest. This would make sense since the fewer sagebrush plants would have more water resources for growth because Williams et al. (2002) reported no difference in grass biomass between 4 and 14 kg pls/ha grass seeding rates after 2 growing seasons. Canopy volume per plant increased by 10-fold between 2004 and 2010.

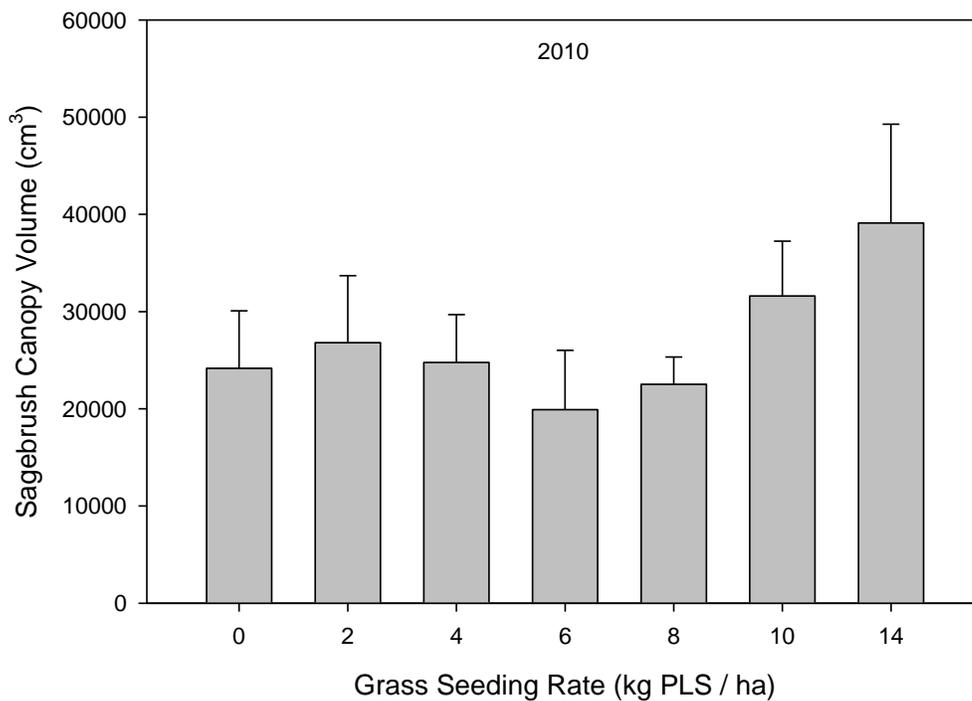
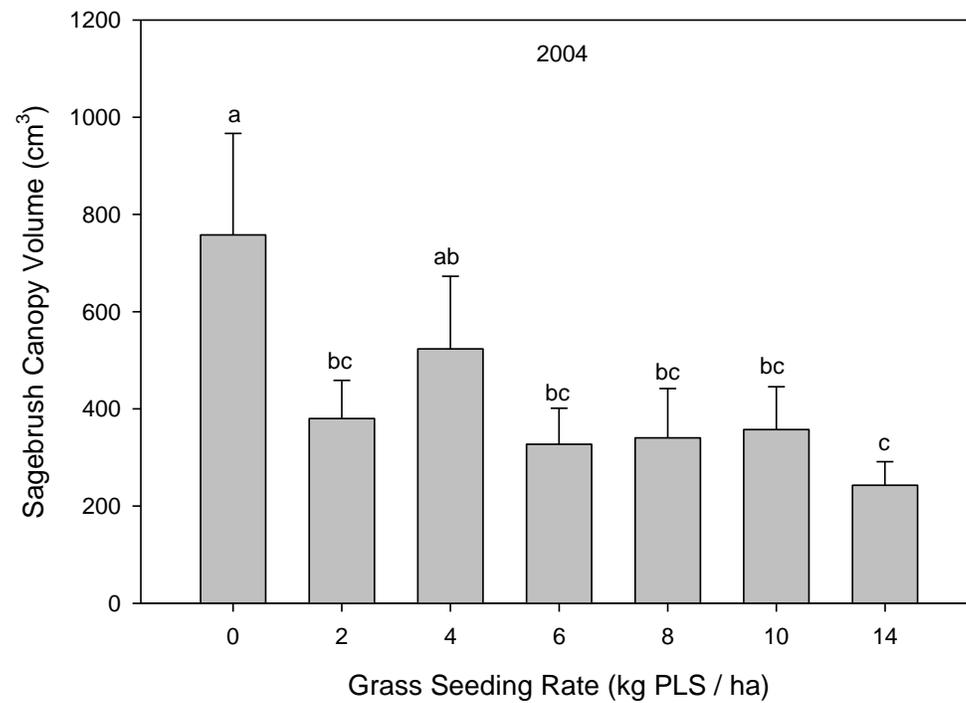


Figure 3. The effect of grass seeding rate on Wyoming big sagebrush canopy volume (cm<sup>3</sup>) per plant, Belle Ayr Mine, Gillette, WY, 2004 and 2010. (Bars with the same lower case letter in 2004 are not significantly different; the 2010 data were not significant).

Mean big sagebrush canopy volume on a per m<sup>2</sup> basis also increased dramatically between 2004 and 2010; nearly 1300%. In 2004 the greatest volume/m<sup>2</sup> was observed at the 0 grass seeding rate; however, in 2010 little difference existed between the grass seeding rates, Fig. 4. These levels of canopy volume provide significant variance to the structural aspects of the reclaimed plant community and provide wildlife habitat.

#### Wildlife Habitat Benefits

Since wildlife habitat is a primary pre- and post-mining land use of the coal mined lands in Wyoming, the reclaimed plant community is expected to support the wildlife. Wyoming big sagebrush provides resources throughout the year for antelope (*Antilocapra americana*) and sage grouse (*Centrocercus urophasianus* Bonaparte) (Olson et al., 2000). Sagebrush height and cover for antelope as published by Cook (1984) for Wyoming are 22-46 cm and 10-38%, respectively. Postovit (1981) reported sagebrush requirements for sage grouse height and cover to be 26.6 cm (nesting), 18 cm (summer) and 22cm (winter) and cover at 5.5% (general) and 25% (nesting). The mean height across sagebrush seeding rates and grass seeding rates was 45.8 cm and the cover 22.9%. This data indicates that the Wyoming big sagebrush height and cover provide adequate/good habitat for antelope and sage grouse. Postovit (1981) also reported that the sagebrush density requirements for sage grouse should be 1.5 plants/m<sup>2</sup> for general habitat and 2.9 plants/m<sup>2</sup> for nesting. As mentioned earlier a density of 2.2 shrubs/m<sup>2</sup> was obtained in our study which exceeds the general density requirement for sage grouse and approaches that for nesting. It is important to note that to achieve this quality of wildlife habitat takes several years on reclaimed coal mined lands in northeastern Wyoming. The time required to achieve acceptable wildlife habitat for these two important wildlife species will vary and depend upon the reclamation practices utilized and the climatic conditions, particularly precipitation, following initial revegetation.

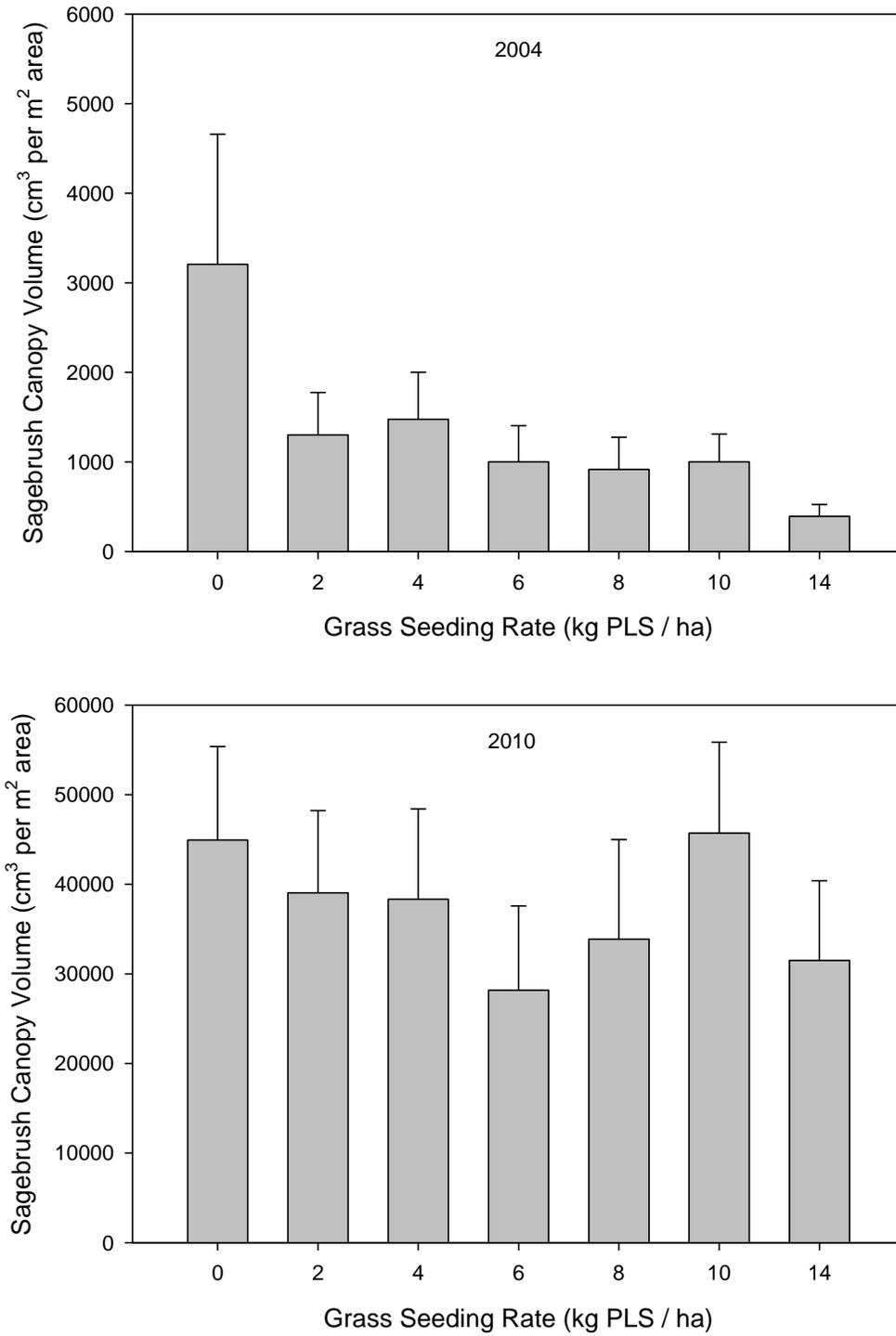


Figure 4. The effect of grass seeding rate on Wyoming big sagebrush canopy volume per m<sup>2</sup>, Belle Ayr Mine, Gillette, WY, 2004 and 2010.

### **Recommendations**

Based upon 13 years of data, the authors feel confident in recommending practices that achieve these desired characteristics of a reclaimed plant community that meet the regulations for coal mined lands in Wyoming; landscape stability, overall production, and wildlife habitat. Levels of grass seeding should be reduced from the “typical” grass rates and Wyoming big sagebrush rates should be increased. By thoroughly evaluating the data presented here and that reported by Williams et al. (2002) and Hild et al. (2006), the authors feel comfortable and justifiable in recommending grass seeding rates of 6-8 kg pls/ha and Wyoming big sagebrush seeding rates of 2-4 kg pls/ha to ensure desired reclamation that meets regulatory requirements and provides good revegetation, forage productivity and wildlife habitat. These grass seeding rates gave good vegetative production and soil stability and yet did not create excessive competition for Wyoming big sagebrush seedling establishment and growth. The seemingly high sagebrush seeding rates provide a seed bank that allows for multi-year germination and establishment of big sagebrush to occur when good precipitation and temperature conditions exist. Schuman et al.(1998) and Schuman and Booth (1998) found that sagebrush seed remained viable and resulted in continued seedling established 3-4 years after seeding.

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