Cultural Methods for Enhancing Wyoming Big Sagebrush Seed Production

D. T. Booth
Y. Bai
E. E. Roos

Abstract: Demand for sagebrush seed is expanding, but wildland harvesting is impaired by several factors including loss of stands to weed invasions and fire. To increase the potential for seed production, sagebrush seed harvests were compared among cultural treatments for stands on a coal mine near Glenrock, WY. Sagebrush in the study were mature plants on unmined rangeland (age unknown) and 5- to 20-year-old plants on reclaimed land. Plants on mined land protected by 1- by 1- by 1-m fence of 2.5-cm wire net had a 3-year average seed yield of 20.7 g per plant compared to 5.2, 1.4, and 0.9 g per plant from plants on unmined-fenced, mined-unfenced, and unmined-unfenced rangelands. Fencing prevented browsing by herbivores and had a beneficial influence on plant microclimate. Seed weight was greater where mulch or other treatments mitigated environmental stress. We conclude that the quantity and quality of Wyoming big sagebrush seed harvest can be increased for existing stands, particularly those on mined land, by protecting the plants from large-animal herbivory and by using methods such as windbreaks and fabric mulch to mitigate the effects of drought.

Introduction

Wyoming big sagebrush (*Artemisia tridentata* Nutt. ssp. *wyomingensis* [Beetle & Young]) is used for ecological restoration of areas disturbed by fire, mining, cropping and other situations requiring artificial revegetation with native shrubs. That use has made Wyoming big sagebrush seed a regionally important specialty crop with a history of sustained demand over more than a decade (R. Dunne, CEO, Wind River Seed, personal communication; J. Johansen, Natural Resource Specialist, BLM Regional Seed Warehouse - Boise District, personal communication). While the demand for seed has been steadily increasing, native stands suitable for seed harvesting have been steadily decreasing due to fire and invasion by weeds. The situation suggests a need to manage selected sagebrush stands, such as those on reclaimed mined lands, for improved seed production. Here we review work conducted to access the quality and quantity of seed that could be harvested from existing stands of sagebrush at the Dave Johnston Coal Mine near Glenrock, WY (Booth and others 2003).

Study Site Description

The Dave Johnston Coal Mine is 40 km east of Casper, WY, at an elevation of 1,646 m. The mean annual precipitation is 328 mm and the mean annual temperature is 8.8 °C (Martner 1986; Owenby and Ezell 1992) with an average 123 frost-free days per year. Soil parent material is Cretaceous clay shale (Young and Singleton 1977). Five sites were located on the mine where mined-land sagebrush stands were in close proximity to stands of sagebrush on unmined rangeland. These sites ranged in age from 5 to more than 20 years at the start of the study (table 1).

Experimental Design and Treatments

The experimental design was a split plot, 2 by 2 factorial replicated among the five sites with whole plots being mined and unmined land at each site and subplots being cultural treatments. Cultural treatments were assigned to single sagebrush plants selected for uniformity and are described as follows: (1) understory plants were cut to ground level, and a 1-m^2 piece of fabric mulch (Appleton and others 1990) was installed around the base of the plant; (2) a windbreak of fabric mulch was erected on the north and west side of the plant, (3) both mulch and a windbreak were installed, and (4) the selected plant was not treated (neither windbreak nor mulch). Three subsamples (individual plants) were used for each treatment combination. Treatments were installed in July 1995.

A 1-m^2 by 1-m-high fence of 2.54-cm wire net was placed around plants selected for treatment. Fenced plants were paired with a similar-size, unfenced, untreated adjacent plant (table 1). Our test included an evaluation of any effects of the wire net because we needed to protect experimental plants from browsing wildlife, and we needed to measure the effect of our protective measures.

Soil moisture was measured using gypsum blocks buried to 10 cm below the soil surface and beneath the canopy of treated plants. The blocks were read midmonth, May through

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D. T. Booth is a Rangeland Scientist, USDA-ARS, High Plains Grasslands Research Station, 8408 Hildreth Road, Cheyenne, WY 82009, U.S.A., e-mail: tbooth@lamar.colostate.edu. Y. Bai is an Assistant Professor, Department of Plant Sciences, University of Saskatchewan, 51 Campus Drive, Saskatoon, Saskatchewan S7N 5A8, Canada. E. E. Roos is Assistant Area Director, USDA-ARS, Northern Plains Area, 1201 Oakridge Dr., Fort Collins, CO, 80525, U.S.A., formerly Research Leader and Plant Physiologist, National Seed Storage Laboratory.

Table 1—Experimental variables used in sagebrush seed production study.

Variable (number and identification)
Sites (5; Fuel Island, Entry 50, 110 School, 60 Badger, 4 School)
Whole plots (2; mined and unmined)
Subplots (4 treatments x [3 subsamples + 3 paired plots] = 24 as indicated below)
Mulch plots with paired untreated and unfenced plots (3 + 3)
Windbreak plots with paired untreated and unfenced plots (3 + 3)
Mulch + windbreak plots with paired untreated and unfenced plots (3 + 3)
Control plots with paired untreated and unfenced plots (3 + 3)

September 1996 through 1998. The data were analyzed by month across the 3 years of the study.

Seeds were harvested annually in late October or early November 1996 through 1998. Data collected included number of seed stalks and bulk weight of seeds produced per plant; and seed weight, moisture content at harvest, germination, and seedling vigor. Seed quality tests used 20 seeds per plant or the maximum number of seeds available if less than 20. The methods used for seed-quality testing are described elsewhere (Bai and others 1997; Booth and Griffith 1994; Booth and others 2003). We used the "Mixed" procedure in SAS to test for differences among variables and the "differences" option to compare least-square means (Littell and others 1996; SAS 1996). Protective fencing was evaluated in separate analyses as a subplot effect (table 2).

Results

Seed Yield

To our surprise, more seed was harvested from mined land than from adjacent unmined rangeland. There was no difference between mined and unmined land in the number of seed stalks counted at seed harvest, but plants on mined land yielded more seed in all 3 years of the study. The extent of the harvest was a factor of protective fencing. Fence-protected plants produced greater seed stalk numbers (table 3), and greater seed yield per plant (bulk weight). Protected plants on mined land yielded 3 to 6 times more seed than protected plants on unmined land (fig. 1).

Compared to the effects of land type and fencing, mulch and windbreak had a relatively minor effect on yield. Mulch was a significant ($P \leq 0.10$) factor in only 1 year and then as part of a three-way interaction (table 4). Windbreak interacted with other factors to have a significant influence ($P \leq 0.10$) on seed yield in 2 of the 3 years.

Seed Quality

Fenced plants produced heavier seeds in 1996 and 1997, but not in 1998 (table 3). Average seed dry weight had some influence of land x mulch in 1997 and mulch in 1998 (table 5). Seed moisture at harvest was similar among cultural treatments, but fenced plants consistently had higher seed moisture than unfenced plants (table 3). This may indicate residual food storage activity in the seeds, and may account for the trend for fenced plants to produce heavier seeds.

We found no differences in germination or dormancy due to treatments, fencing, or types of land. Mean germination percentages ranged between 39 and 92 percent from unmined land, and between 77 and 92 percent from mined land. Percentage dormant seeds (those that did not germinate but remained firm throughout the test period) ranged from 3.5 to 23.7 percent in 1996, 1.0 to 6.8 percent in 1997, and 1.2 to 8.4 percent in 1998. (Note the tendency for a correlation between increasing seed dormancy with lower seed yield [compare dormancy range with fig. 1]. It would be interesting to learn if this apparent correlation is real.)

Means for seedling axial length in our test of seed vigor ranged from 23 to 34 mm. There were no differences due to land or fencing in 1997 or 1998 ($P \geq 0.57$), and in 1996 there were not enough seeds harvested to compare treatments.

Table 2—Example programs, with model statements, as submitted to SAS for fenced, and fenced-versus-unfenced plot analysis.

Fenced	Fenced versus unfenced
Proc mixed;	Proc mixed;
Class site land mulch windbreak replication;	Class site land fence replication;
Model bulk weight =	Model bulk weight =
Land	Fence
Mulch	Land
Land x mulch	Land x fence;
Land x windbreak	Random site; site x land
Land x mulch x windbreak;	Ismeans fence land x fence/difference; run
Random site; site x land	
Ismeans land mulch x windbreak	
Land x mulch x windbreak/difference; run	

Table 3—Effect of protective fencing on means of sagebrush seed stalks per plant, weight of sagebrush seeds, and seed moisture 1996 to 1998. The observed significance level is given for each pair of means.

Variable	1996 Fenced	1996 Unfenced	1997 Fenced	1997 Unfenced	1998 Fenced	1998 Unfenced
Number seed-stalks	22	4	56	10	76	15
OSL[a] (df = 48)	P < 0.01		P < 0.01		P < 0.01	
Seed weight (mg per seed)	0.1507	0.0708	0.2483	0.1422	0.2325	0.1916
OSL[a] (df = 48)	P = 0.01		P < 0.01		P = 0.29	
Seed moisture (percent)	3.9	1.3	5.6	3.1	4.0	2.5
OSL[a] (df = 48)	P < 0.01		P < 0.01		P = 0.02	

[a]Observed significance level.

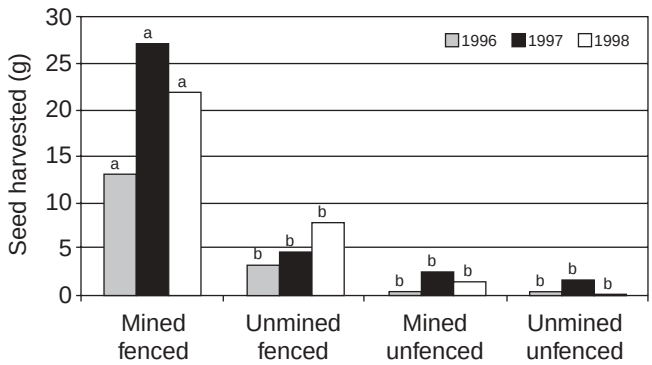

Figure 1—Mean bulk weight of sagebrush seeds per plant by year as affected by type of land and protective fencing. The OSL for the land x fence interaction was P = 0.03, 0.03, and 0.05 in 1996, 1997, and 1998. Means within a year followed by the same letter are not different at P ≤ 0.05 as indicated by differences in least square means within the "Mixed" statistical procedure (SAS 1996).

Table 4—Mean bulk weight of sagebrush seeds per fenced plant by year as affected by type of land, mulch, and windbreak[a].

Year	Land status	Mulch	Windbreak	Bulk weight seeds
				- - g - -
1996	Mined	yes	No	25.5a
	Mined	No	Yes	21.8ab
	Mined	No	No	13.0b
	Mined	Yes	Yes	12.7b
	Unmined	Yes	Yes	4.3b
	Unmined	Yes	No	3.9b
	Unmined	No	No	3.1b
	Unmined	No	Yes	2.4b
1997	Mined	–	No	29.9a
	Mined	–	Yes	20.1b
	Unmined	–	Yes	8.6b
	Unmined	–	No	6.0b
1998	Mined	–	–	19.1 (P = 0.10)
	Unmined	–	–	4.4

[a]Observed significance level: 1996 land x mulch x windbreak P = 0.06; 1997 land x windbreak P = 0.07; and 1998 land P = 0.10; df: land = 4, windbreak = 102, mulch = 102, interactions = 104. Means within a year followed by the same letter are not different at P < 0.05 as indicated by differences in least-square means within the "Mixed" statistical procedure (SAS 1996).

Soil Moisture (Fenced Plants Only)

Soil moisture in May was influenced by site x land x mulch (P = 0.05), land x mulch x windbreak (P < 0.01), year x mulch (P < 0.05), year x land (P < 0.01, and year x site (P < 0.01). The interactions with site and year were expected. The three-way interactions (table 6) reveal that mined-land soils had soil moisture equal to or greater than that of unmined lands. The greatest soil moisture occurred on mined land with mulch and windbreak.

June soil moisture interactions were site x land (P = 0.02), year x mulch (P = 0.04), and year x site (P < 0.01). The site x land data again indicated that mined-land soil moisture was equal to, or greater than that of unmined lands (table 7). There were no differences in main effects or interactions for July (P ≥ 0.83), and year x site was the only significant interaction in August and September (P < 0.01 for both months).

Plant Mortality

There were three mined-land plants in the study that died at 110 School (12.5 percent) and 11 that died at 60 Badger (46 percent). (Note the high soil moisture for mined land at 60 Badger [table 7].) All mortality during the 3 years occurred on mined land; there was no mortality at any of the other study sites.

Table 5—Seed quality: mean weight of sagebrush seeds by year as affected by land type and mulch[a].

Year	Land status	Mulch	Seed weight	OSL[b]
			- - -mg - - -	
1996	Mined	–	0.21	P = 0.22
	Unmined	–	0.11	
1997	Unmined	Yes	0.33a	P = 0.09
	Mined	Yes	0.28ab	
	Mined	No	0.27ab	
	Unmined	No	0.24b	
1998	–	Yes	0.28	P = 0.09
	–	No	0.24	

[a]Multiple means within a year followed by the same letter are not different at P < 0.05 as indicated by differences in least-square means using the "Mixed" statistical procedure (SAS 1996). Degrees of freedom: land = 4, mulch = 104, windbreak = 104, interactions = 104.
[b]OSL = Observed significance level.

Table 6—Mean percentage soil moisture for May averaged over 5 years and as affected by land, mulch, and windbreak.

Windbreak	Mulch	Mined	Unmined	OSL[a] for land
		- - - - *percent* - - - -		
Yes	Yes	72.8	62.6	<0.01
Yes	No	59.6	55.6	.09
	OSL for mulch	<0.01	<0.01	
No	Yes	69.3	66.5	.29
No	No	69.7	58.4	<0.01
	OSL for mulch	.87	<0.01	

[a]Observed significance level.

Table 7—Mean percentage soil moisture for June averaged over 3 years as affected by site and land.

Site	Mined	Unmined	OSL[a] for land
	- - - - - - *percent* - - - - - - -		
Fuel Island	20	16	0.55
Entry 50	36	27	.16
110 School	31	37	.36
60 Badger	70	45	<0.01
4 School	35	21	.03

[a]Observed significance level.

Discussion

Why Were Seed Yields Greater on Mined Versus Unmined Land?

Seed yields from fenced plants on mined land were consistently greater than for other treatment combinations. This may have been due to soil moisture, which was usually greater under mined-land plants in May and June. Why these soils contained more moisture is a matter for speculation. Conceivably plant density—either of shrubs or of all plants—was lower on mined land. Plant density often affects seed yield and differences in soil moisture may be only one aspect of that affect (Henderson and others 2000; Holen and others 2001; Lopez-Bellido and others 2000; USDA 1961). Given that seed quality as measured by seed weight, seed moisture, germination, and seedling vigor (axial length) was not affected by land status, the greater seed yield for mined land suggests seed producers might wish to direct cultural efforts to mined-land stands.

Fenced and Unfenced Plants

It is clear that large herbivores reduced seed production by eating seed stalks (table 4). Wagstaff and Welch (1991) also reported that protected sagebrush plants produce significantly more seed stalks than plants not protected from grazing animals. We recognize that protective fencing modified the environment in favor of the protected plants. However, the report of Gores (1995), and personal observations of the effects of wildlife on mined-land shrub stands suggest the bias was relatively insignificant and should not be used to underrate wildlife herbivory as a factor limiting seed production of mined-land sagebrush.

Environmental Modification by Fence, Windbreak, and Mulch

We found that surrounding a sagebrush plant with wire netting (fenced) resulted in a beneficial modification of its environment as evident by greater seed weights from protected plants (table 4). This was not expected, especially with the large (2.54-cm) net used. The fencing affect may account for the minimal effect of mulch and windbreak on seed production and quality. Mulch and windbreak did influence seed production and quality, but these effects were not consistent. The mulch, due to its small size (1 m^2), did not always result in greater soil moisture (table 7). A larger piece of fabric would have shown a more consistent benefit to soil moisture, shrub growth, and seed production (Booth, unpublished data).

Conclusions and Recommendations

Wyoming big sagebrush on reclaimed mined lands similar to those of the Dave Johnston Coal Mine have the potential to produce more seeds than plants from adjacent unmined land. However, the mined-land seed-production advantage will be realized only when the plants are protected from browsing wildlife. Environmental modification—particularly the use of fabric mulch—can also improve seed production and some factors of seed quality, but these efforts are viewed as secondary to that of excluding browsing animals.

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