ESTABLISHING

# Wyoming Big Sagebrush

## SEED ORCHARDS ON RECLAIMED MINED LAND

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ABSTRACT

Reclaimed mined lands often have restricted public access, a situation that could encourage sagebrush seed growers to invest in methods for increasing seed production and improving seed purity and quality. I tested the agronomic benefit of 2 seeding methods and fabric mulch and a cross-linked polyacrylamide polymer soil amendment by using these practices to establish 3 Wyoming big sagebrush (*Artemisia tridentata* Nutt. ssp. *wyomingensis* Beetle & Young [Asteraceae]) seed orchards on a reclaimed uranium mine in Wyoming's Shirley Basin. Seed yield was monitored for 5 y. Cased-hole punch seeding (CHPS) produced more and faster growing plants than broadcasting. Seeds from plants established through mulch averaged 20 to 36 g (0.7 to 1.3 oz) per plant compared with less than 10 g (0.4 oz) per plant without mulch. Polyacrylamide-amended soil produced fewer seeds than untreated plots in every year of the study. Fabric mulch clearly enhanced sagebrush growth and seed yield; polyacrylamide did not.

Seeds of sagebrush, like these basin big sagebrush (*Artemisia tridentata* spp. *tridentata*), could be produced in seed orchards. Photo by Sam E Cox

KEY WORDS
cased-hole punch seeding, CHPS, fabric mulch, polyacrylamide, seed wafers, stand establishment, seed yield

NOMENCLATURE
USDA NRCS (2004)

Demand for sagebrush (*Artemisia tridentata* Nutt. [Asteraceae]) seeds is expanding, but wildland harvesting is affected by several unfavorable factors including loss of stands to weed invasions and fire. Sagebrush seeds are needed for ecological restoration projects throughout the western US with fire rehabilitation contributing to a major increase in demand—so much so that seed poachers can be a problem for government agencies (Associated Press 2000). The Utah Division of Wildlife Resources, Great Basin Research Center website valued Wyoming big sagebrush seed at US$ 13.05 per bulk kg ($5.92/lb) on 18 January 2005 (UDWR 2005).

Sagebrush seeds are harvested predominately from public lands, but this has the seed-production disadvantages of uncontrolled access and multiple-use land management with little incentive for seed harvesters to provide cultural inputs for improved seed production and quality. Wildland stands are likely to continue to provide the bulk of seed, but seed production might be supplemented by seed orchards on reclaimed mined lands. Often these sites offer a desirable alternative to public-land seed harvesting because access is controlled and stands can be specifically managed for seed production. Such an arrangement could benefit both the mining company and the seed harvester. Enhanced seed production in mined-land seed orchards may enhance the mining company's ability to achieve required post-mining shrub density and composition performance standards (WDEQ 2002). Surprisingly, evidence exists that mined lands may yield a greater quantity and quality of sagebrush seed than is produced on non-mined lands, also that fabric mulch used in appropriate quantity might consistently influence sagebrush seed production and quality (Booth and others 2003). To develop information on the practicality of managing mined-land sagebrush for seed production and to follow up on work conducted by Booth and others (2003), I tested the hypotheses that fabric mulch and polyacrylamide soil amendment would enhance stand establishment and seed yield of Wyoming big sagebrush (*Artemisia tridentata* Nutt. ssp. *wyomingensis* Beetle & Young).

## MATERIALS AND METHODS

### Site Description

The study was conducted at a large, open-pit, reclaimed uranium mine in Wyoming's Shirley Basin (lat 42°21'34" N, long 106°11'08" W)—a geographic region noteworthy for the initial release, in 1991, of 49 juvenile blackfooted ferrets (*Mustela nigripes*) that re-established a wild population of this rare North American mammal. Shirley Basin has an average annual precipitation of 267 mm (10.5 in) and a 90% chance of having 93 consecutive frost-free days (WRCC 2003). Annual precipitation for the years of the study is presented in Table 1.

The pit is an oblong bowl about 1.8 x 2.7 km (1.1 x 1.7 mi) at the top and about 0.8 x 1.8 km (0.5 x 1.1 mi) at the bottom (Figure 1). The top of the spoil pile on the west edge of the pit has an elevation of 2200 m (7217 ft) above sea level and the elevation near the 2 lakes at the bottom of the pit is 2080 m (6824 ft) above sea level. Mining removed both White River (bentonitic arkosic sands interbedded with fine silts and montmorillonitic clays) and Wind River (high silt and clay content with scattered lenses of arkosic sands in the upper portion of the formation) geologic materials as overburden (Schuman and others 1985). During reclamation, spoil materials were covered with 15 to 30 cm (6 to 12 in) of topsoil (pH = 7.2)(Murdock 2005) before being seeded to an annual grain as a cover crop and stubble mulch. Our study sites were three 9 x 12 m (29.5 x 39 ft) fenced plots located at the top (west), mid-elevation (west), and bottom (east) of the pit and designated Replications 1 through 3, respectively. They were seeded during the fall of 1994 and were visited annually through fall of 2001.

### Soil Treatments

Polypropylene woven-fabric mulch in 1.8 x 7 m (6 x 23 ft) strips, and the incorporation of 1 kg/10 $m^2$ (2.2 lb/12 $yd^2$) cross-linked polyacrylamide polymer as a soil amendment for increasing the soil water-holding capacity, were tested in a 2 x 2 factorial design for their ability to promote shrub establishment and seed production. The polymer was rototilled into a depth of 14 cm (5.5 in). The fabric mulch was anchored in place with 8 x 15 cm (3 x 6 in) wire staples placed at 61 cm (24 in) intervals across the fabric.

### Shrub Seeding Treatments

Cased-hole punch seeding (CHPS) is a planting method in which a punched hole is cased with plastic tubing. The demonstrated advantages of punch planting are that moisture, temperature, and the concentration of soil salts in the immediate vicinity of the seed are more desirable than at the soil surface (Cary 1967; Hauser 1982). The problem with punch planting has been that the punched holes slough and bury the seeds too deeply. Casing the hole prevents sloughing. I invented the concept and a hand tool to facilitate punching, casing, filling casings with potting soil, and seeding the casing (Booth 1995; Figure 2). This tool was used to seed sagebrush in this study using 1.3 cm (0.5 in) diameter, 7.6- and 12.7-cm (3- and 5-in)-long casings. CHPS was compared to broadcast seeding. Broadcasting through the fabric mulch was accomplished by burning a hole in the fabric, then broadcasting seeds onto the soil surface. An installed 7.6-cm (3-in) casing had 2.5 cm (1 in) of casing above the soil surface with 5.1 cm (2 in) below the surface and leaving 2.5 to 3 cm (1 to 1.2 in) of casing headspace above the soil surface inside the casing. A 12.7-cm (5-in) casing also had 2.5 cm (1 in) projecting above the soil surface and the same headspace (Figure 3). During an initial attempt to seed the plots it was observed that wind was sucking sagebrush seeds out of installed casings and blowing seeds away from broadcast seed spots. To reduce the amount of seeds lost to wind, seed wafers were prepared before going to the field to seed Replications 2 and 3. The wafers were made by mixing wheat flour and water to make a paste, dropping the paste onto wax paper, then pressing 3 pure live seeds (PLS) onto the 2 x 5 mm (0.1 x 0.2 in) wafers (part of the seed remained exposed). Germination of seeds on wafers was tested and found not to be different from non-wafered seeds (data not shown). In the field, the wafers were dropped into the casings or onto the seed spot. Two replications were seeded with wafers during fall 1994 and a third was reseeded (using wafers as used in the other replications) in fall 1995. Seed spots were located at 30-cm (11.7-in) intervals in rows 60 cm (23 in) apart.

TABLE 1 *Annual precipitation (mm) for the years of the study (WRCC 2003).*

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1994 | 11 | 8 | 10 | 28 | 25 | 15 | 22 | 22 | 11 | 46 | 24 | 42 | 246 |
| 1995 | 5 | 10 | 85 | 48 | 119 | 65 | 36 | 10 | 114 | 49 | 12 | 28 | 505 |
| 1996 | 17 | 2 | 11 | 40 | 51 | 9 | 11 | 3 | 18 | 35 | 13 | 13 | 225 |
| 1997 | 16 | 23 | 10 | 14 | 49 | 43 | 34 | 74 | 20 | 14 | 1 | 6 | 285 |
| 1998 | 10 | 24 | 24 | 0 | 12 | 60 | 73 | 36 | 27 | 86 | 17 | 4 | 372 |
| 1999 | 21 | 12 | 16 | 59 | 28 | 54 | 11 | 8 | 27 | 4 | 11 | 9 | 258 |
| 2000 | 12 | 28 | 18 | 58 | 49 | 21 | 1 | 22 | 40 | 11 | 15 | 15 | 251 |
| 2001 | 7 | 14 | 8 | 41 | 18 | 11 | 113 | 24 | 17 | 28 | 9 | 6 | 288 |
| **Mean** | **12** | **15** | **23** | **36** | **44** | **35** | **38** | **25** | **34** | **34** | **13** | **15** | **304** |

10 mm = 0.4 in

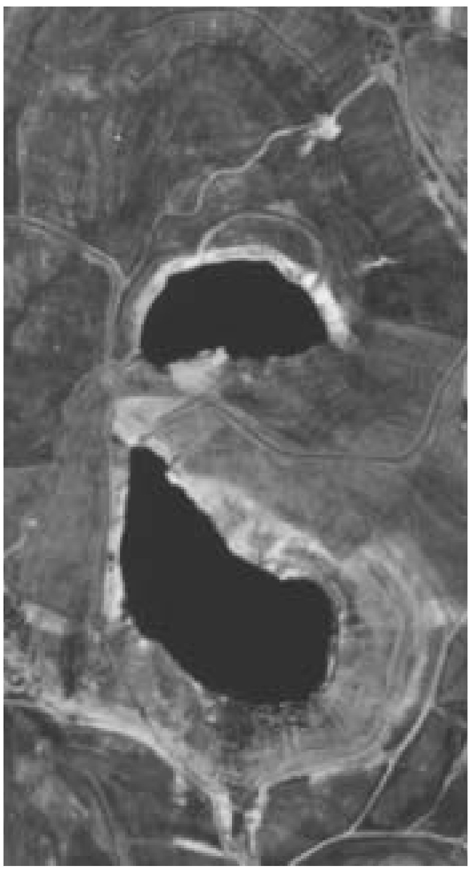


*Figure 1.* USGS aerial photograph of open-pit, reclaimed uranium mine in Wyoming's Shirley Basin (UTM: N. hemisphere, Zone 13, Easting 403 188 m, Northing 4 691 056 m.) Source resolution was 1000 meters per pixel. Image captured July 1994.

Photo by LW Griffith

Photo by DT Booth

*Figure 2.* Cased-Hole Punch Seeder close up (left) , and as used to plant through fabric mulch (right).

Photos by LW Griffith

*Figure 3.* Cased-Hole Punch Seeding casing planted through fabric mulch and showing casing headspace with a 2-year-old Wyoming big sagebrush seedling.

*Figure 4.* Wyoming big sagebrush established using Cased-Hole Punch Seeding with 12.7-cm casings, fabric mulch, and no polyacrylamide soil amendment. Date of the photograph was 30 October 1997.

### Monitoring Seedling Heights and Seed Production

Annually in late October or early November, 1996 through 2001, the sagebrush height was measured and seeds harvested (Figure 4). Seeds were harvested by clipping seed heads and placing them in labeled paper bags for transport to the laboratory. Subsequently, seed heads were weighed, seeds stripped from seed heads, seeds cleaned to an average 5% purity (1997 through 2001), and reweighed. Seed weights for yields were determined by taking a 1-g (0.04-oz) sample from the cleaned material (~5% purity), then separating, counting, and weighing separated seeds (mostly achenes—that is, with pericarps attached), and using this information to calculate total seeds harvested for each plant.

### Experimental Design and Statistical Analysis

The experimental design was a randomized complete block with 3 replications. Data were statistically analyzed using the "Mixed" procedure in SAS (SAS 1988, 1996; Littell and others 1996).

## RESULTS AND DISCUSSION

### Stand Establishment and Growth

Sticking sagebrush seeds to flour wafers proved to be an effective seeding method. First-year establishment over all treatments for Replication 3 (seeded without wafers) was 15 successful seed spots out of 240 (6%). The 2 replications where wafers were used had 29% (Replication 1) and 33% (Replication 2) success. Of the pure live seeds (PLS) sown on wafers, 11% produced a sagebrush plant. These values compare with 1% and < 0.01% PLS from conventional broadcast seedings as reported by Luke and Monsen (1984) and Booth (2002). The difference in this study between wafers (11%) and loose seed (6%) is significant ($P > 0.01$) as tested by confidence intervals calculated using the normal approximation (Steel and Torrie 1980, p 479). Of course location is a potentially confounding variable in replication comparisons. However, the 1996 count of successful seed spots (after Replication 3 was reseeded with wafered seed during fall 1995) was 28, 31, and 44% for Replications 1 to 3, respectively. This suggests that location was not a confounding factor and that the 1995 difference among replications in seedling establishment can be attributed to seeding method.

CHPS resulted in greater seedling establishment and also in greater seedling heights into the second growing season. The 12.7-cm (5-in) casing was more beneficial than other treatments (Table 2). Sagebrush grown with mulch reached heights more than double that of plants without mulch during the first 3 y of data collection (1996 to 1998), and the height difference remained highly significant through 6 y (1996 to 2001) (Figure 5).

TABLE 2 *Sagebrush seedling numbers and mean heights (mm), over 3 replications, by year and seeding treatment. Plots were seeded December 1994, and 1 replication was reseeded November 1995.*

| Year | Broadcast | 7.6-cm casing | 12.7-cm casing |
|---|---|---|---|
| *1996* | | | |
| Seedling number | 16 | 93 | 139 |
| Mean height | 74 | 111 | 136 |
| Standard deviation | 72 | 110 | 111 |
| P value | | 0.04 | |
| Proc. Mixed diff. of Least Square Means: 7.6-cm casing versus 12.7-cm casing, $P = 0.87$; 7.6-cm casing versus broadcast, $P = 0.01$; and 12.7-cm casing versus broadcast, $P = 0.02$. | | | |
| *1997* | | | |
| Seedling number | 18 | 86 | 126 |
| Mean height | 166 | 233 | 278 |
| Standard deviation | 158 | 165 | 165 |
| *P* value | | 0.16 | |
| *1998* | | | |
| Seedling number | 16 | 85 | 126 |
| Mean height | 244 | 314 | 346 |
| Standard deviation | 178 | 183 | 181 |
| *P* value | | 0.52 | |

10 mm = 1 cm = 0.4 in.

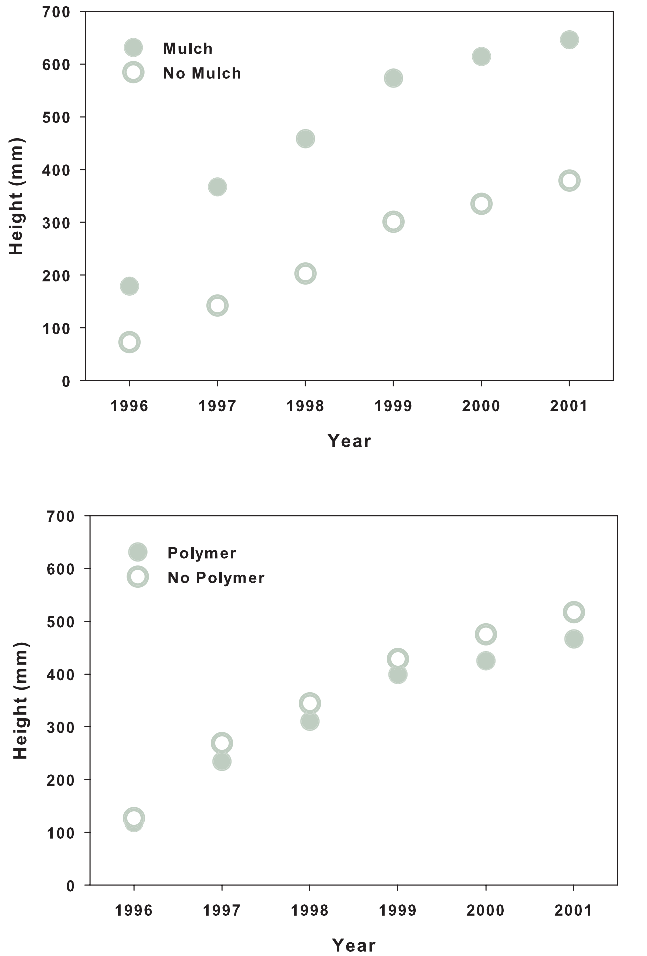
The polyacrylamide soil amendment did not enhance sagebrush growth and probably inhibited growth because sagebrush without the polymer consistently had greater heights (Figure 5). The interactions (seeding method x mulch, seeding method x polymer, mulch x polymer, and the 3-way) were not significant for any year and ranged from $P = 0.23$ to 0.98 for all years except 1997. (In that year, seeding method x mulch, $P = 0.12$; seeding method x polymer, $P = 0.11$; mulch x polymer, $P = 0.43$; and the 3-way interaction, $P = 0.15$.)

## Seed Production

In 1996, which was the second growing season for 2 of the replications, 9 plants produced 546 seeds. Most seeds, 76%, were produced from fabric mulch and no polymer, 23% were produced with both mulch and polymer, and no seeds were produced by treatments having polymer alone, or neither mulch or polymer. All seeds came from plants established from CHPS. The following year, 97% of the seeds came from treatments having fabric mulch and using CHPS. Again, no seeds were produced from polymer alone or neither mulch or polymer. Mulch significantly ($P \leq 0.05$) increased seed production during 1998 through 2001 (Figure 6). The difference in seed production between treatments with and without polymer was not significantly different year by year ($P > 0.25$); however, mean yield was always greater for the no-polymer treatment (Figure 6).

## IMPLICATIONS

This study clearly demonstrated the value of fabric mulch for enhancing sagebrush seedling growth and seed production, and the inadequacy of polyacrylamide for accomplishing the same purpose. The installation of sagebrush seed orchards consisting of a single shrub per $m^2$ (1.2 $yd^2$) over 0.5 to 1 ha (1.2 to 2.5 acres) is a density and an orchard size consistent with state regulations requiring shrub patches on reclaimed rangeland (WDEQ 2002). Establishing sagebrush patches with fabric mulch, then managing the patches for seed production, is a potential means for addressing the sagebrush seed shortage. The rapid growth and large size attained by Wyoming big sagebrush grown with fabric mulch for the purpose of seed production is also likely to benefit local wildlife populations by providing win-



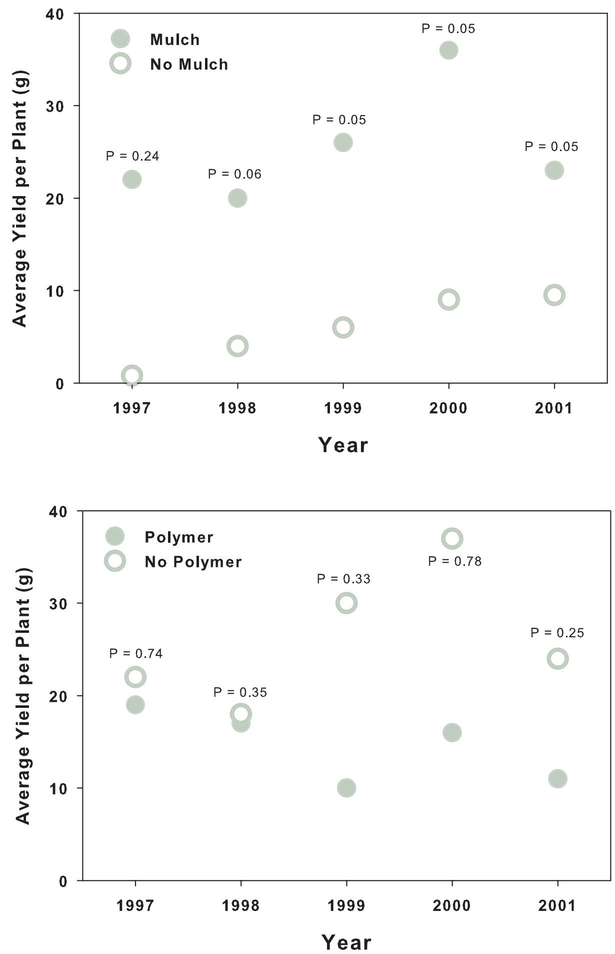




*Figure 5.* Wyoming big sagebrush height by year as affected by fabric mulch (top) and polyacrylamide soil amendment (bottom). The differences for fabric mulch are significant for every year ($P \leq 0.01$) whereas the differences for polyacrylamide soil amendment are not significant for any year ($P > 0.31$).

*Figure 6.* Wyoming big sagebrush yield by year as affected by fabric mulch (top) and polyacrylamide soil amendment (bottom). P-values indicate the probability for a difference between treatments for the year indicated.

ter forage and nesting cover for sage grouse (*Centrocercus urophasianus*) and protective windbreaks for large herbivores. Sagebrush seed orchards should be fenced to prevent large herbivores from browsing seed heads (Booth and others 2003). The use of fabric mulch in the dryland culture of sagebrush need not be limited to seed orchards. Small patches of sagebrush grown with fabric mulch could be distributed across a reclamation area to provide natural seed production or to improve wildlife habitat by rapidly increasing the structural diversity of the plant community. An Internet search (July 2005) for fabric mulch indicated the cost of fabric ranges from US\$ 0.54 to \$2.26/m² (\$0.05 to \$0.21/ft²) depending on the configuration and quantity ordered.

Despite the success of the CHPS method for plant establishment and early growth, it is labor intensive and may not be a cost-effective seeding method except for small areas or with volunteer labor. Mechanized methods of filling and seeding casings in production greenhouse environments may make it more appropriate to use the CHPS casing as a transplantable container for large plantings. That concept—a plastic tube containing a protective headspace and a newly established plant—is being tested for the commercial market by Bitterroot Restoration Inc (Corvallis, Montana) under a Cooperative Research and Development Agreement with USDA Agricultural Research Service and appears to be an economical means of transplanting sagebrush onto reclaimed mined land if appropriate procedures (not plugging the tube bottom by pushing the tube into the soil) are used during planting (Meikle 2003).

## CONCLUSIONS

Wyoming big sagebrush seed production on reclaimed mined land can be increased by the use of woven fabric mulch in seed orchards. Polyacrylamide soil amendment, as used in this study, will not increase shrub growth or seed yield. Fabric mulch will increase both and could be applied to the installation of commercial seed production orchards or used to increase natural seed distribution on reclaimed lands. It can also be used to increase the structural diversity of mined-land plant communities. Use of these methods for increased sagebrush seed production can benefit seed harvesters and vendors, mining companies and other rangeland owners, as well as those public-land management agencies that have a high demand for good quality sagebrush seeds.

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