STRATEGIES FOR ESTABLISHMENT OF BIG SAGEBRUSH (ARTEMISIA TRIDENTATA SSP. WYOMINGENSIS) ON WYOMING MINED LANDS

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EXECUTIVE SUMMARY

STRATEGIES FOR ESTABLISHMENT OF BIG SAGEBRUSH (*ARTEMISIA TRIDENTATA* SSP. *WYOMINGENSIS*) ON WYOMING MINED LANDS

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ABANDONED COAL MINE LAND RESEARCH PROGRAM

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Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis)* is one of the most widely distributed and adapted shrub species in Wyoming and the region. However, its reestablishment on mined lands has generally proven difficult. This research was designed to integrate several shrub establishment approaches in a manner to define effective strategies for establishment of big sagebrush. Specific objectives included: determine the efficacy of direct-applied topsoil for enhanced sagebrush establishment, determine the value of an annual-grain stubble mulch and a surficially applied straw mulch for increasing sagebrush establishment through enhanced moisture conservation and microsite modification, determine the effect of competition from concurrently seeded grasses on establishment of big sagebrush, determine the effect of seeding fourwing saltbush as a pioneer species for enhancing establishment of sagebrush, determine the effect of arbuscular mycorrhizae (AM) on moisture stress tolerance of big sagebrush seedlings, and evaluate the reclamation methods and resulting shrub densities of pre-1985 reclamation.

This research was composed of three field studies and one laboratory/greenhouse study. The field studies were identified as the "Establishment Study", the "Pioneer Plant Study", and the "Survey Study". The Establishment and Pioneer Plant studies were implemented simultaneously at the North Antelope Coal mine about 100 km north of Douglas, Wyoming. The Survey study involved evaluating fourteen pre-1985 reclamation sites representing 7 surface coal mines and 1 open-pit uranium mine in Wyoming. The greenhouse study was conducted at the Plant, Soil, and Insect Sciences Department at the University of Wyoming and was initiated to compliment the Establishment study and enable greater evaluation of the role of AM in sagebrush establishment.

Establishment Study

This study was designed to evaluate three sets of main treatment variables: (1) topsoil management procedures (direct-applied or stockpiled), mulch methods (stubble, straw, stubble + straw, and no mulch), and level of grass competition (no grass and two levels of a concurrently seeded native grass mixture.

Sagebrush seedling densities measured in the study exhibited an interaction between topsoil management, mulch type, and grass competition. Sagebrush seedling densities exhibited a different response in the spring 1992, fall 1992 and spring 1993 compared to the fall 1993 and fall 1994. The large increase in sagebrush seedling densities exhibited between the spring 1993 and fall 1993 was attributed to the wet and cool spring and summer of 1993. Even though 1993 climatic conditions greatly increased sagebrush seedling densities, the density measured in the 1992 and spring of 1993 on the direct-placed topsoil-no competition, mulched treatments exceeded the recently established shrub standard (1 shrub/m^2) for Wyoming. This emphasizes the importance of good cultural practices especially since these sagebrush densities were achieved during a below average (87%) precipitation year. Direct-placed topsoil resulted in 40% more sagebrush seedlings in the spring of 1993. The 1992 soil moisture content of the surface 7.5 cm was always higher on the direct-hauled compared to the stockpiled topsoil. This greater soil moisture aided in the improved sagebrush establishment on the direct-placed treatment. No sagebrush seedlings could be attributed to soil seedbank because control plots in an adjacent study did not have any sagebrush seedlings present. There was no difference in sagebrush seedling densities due to grass competition between 16 and 32 kg PLS/ha for either of

the two topsoil management treatments. However, grass competition reduced sagebrush seedling densities throughout the duration of the study on the direct-placed topsoil treatment where mulch was applied.

Arbuscular mycorrhizae spore numbers were significantly higher on the direct-placed topsoil compared to the stockpiled topsoil. However, mycorrhizal infection of 396 sagebrush seedlings removed from the competition-mulch-soil management treatment plots in June 1993 showed no differences in spite of the difference in AM spore levels observed initially.

The presence of mulch greatly affected sagebrush seedling establishment in 1992. No seedlings were evident in the first year where mulch was not applied. Mulch has been shown to affect seedling microclimate through reduced diurnal temperature fluctuations and increased soil moisture.

Arbuscular Mycorrhizae Study

A greenhouse study was conducted to further examine the influence of AM and seedling age on soil moisture stress tolerance of big sagebrush. A fresh source of topsoil was collected at the North Antelope Coal Company mine. Arbuscular mycorrhizae was eliminated from a portion of the soil using a pasteurization process to represent a non-mycorrhizal topsoil. One hundred and eight 15-cm pots were filled with either fresh topsoil (mycorrhizal) or non-mycorrhizal soil and seeded with sagebrush. At 30, 45, 60, 90, 120, and 150 days of growth, no additional water was applied to eighteen pots of each treatment. Pots were allowed to dry until the sagebrush seedling died and they were removed from the soil and examined for root mycorrhizal infection. Soil water content of the potting soil was determined and compared to a moisture retention curve established for this soil to determine soil water potential.

Sagebrush seedlings from the mycorrhizal treatment exhibited infection on 65-86% of the root segments examined while only 1-2% of the root segments from the non-mycorrhizal treatment exhibited infection. All seedling age groups that were mycorrhizal were able to tolerate greater soil moisture tensions before dying compared to the non-mycorrhizal seedlings. No non-mycorrhizal seedlings survived when water potentials were below -3.3 MPa; however, many mycorrhizal seedlings survived in soils as dry as -3.7 MPa. Sagebrush seedling age and mycorrhizal treatment exhibited an interaction, indicating that as sagebrush seedlings aged the beneficial effects of AM on soil moisture stress tolerance increased. The research clearly indicate that those seedling $\geq$ 120 days of age that are non-mycorrhizal are much less tolerant of soil moisture stress than younger non-mycorrhizal seedlings within the soil moisture ranges experienced in the study.

Pioneer Study

This phase of the research was initiated to evaluate the role of fourwing saltbush as a pioneer plant to enhance the later establishment of big sagebrush and to evaluate the role of this plant in excluding big sagebrush when planted at rates in excess of 2.2 kg PLS/ha. Direct-placed and stockpiled topsoil treatments were assessed and no grass competition was imposed in this study. A small-grain stubble mulch was established on the entire plot area. Sagebrush seeding treatments included: (1) sagebrush seeded in 1992 and 1993, (2) 1992 fallow and sagebrush seeded in 1993, (3) fourwing saltbush seeded in winter 1991 and sagebrush overseeded in 1993,

and (4) control. Seedling densities were measured annually and color pictures were taken of each 1 m^2 quadrat where seedlings were enumerated. Sagebrush seedling heights were also measured.

Total shrub (saltbush and sagebrush) seedling densities was greater on stockpiled topsoil than on direct-placed topsoil. However, there was a significant difference between replications, which confounds the interpretation. The lack of a significant benefit for direct-placed topsoil contrasts with the benefits noted in the Establishment Study and by other research evaluating seedling establishment, nutrient availability, microbial population and water infiltration reported over the past two decades. Whatever the reason, long-term sagebrush seedling survival was greater on the stockpiled topsoil for all seeding treatments. The plots seeded to sagebrush two consecutive years, after five growing seasons and averaged across the stockpiled and direct-placed topsoil treatments, had greater sagebrush seedling densities than those treatments that were fallowed and then seeded to sagebrush a year later. However, the differences observed were quite small considering that the two consecutive seedings resulted in over twice as much sagebrush seed being sown. Sagebrush seedling density was less when seeded after saltbush establishment than when seeded during the first year or after fallowing for one year. Sagebrush seedling height was also less for this seeding treatment; however, the differences observed were not statistically significant. Total shrub density was greater where both the saltbush and sagebrush were seeded. On the surface the data implies that the saltbush reduced sagebrush seedling establishment but when evaluating the seed establishment efficiency and seedling heights within the saltbush-sagebrush treatment it appears that the use of saltbush as a pioneer species neither improved or reduced the establishment of sagebrush. The photographic data provide clear evidence of sagebrush establishment for three and four growing seasons after the last seeding. This is consistent with the data observed in the Establishment Study.

Survey Study

Fourteen, pre-1985 reclaimed mine sites, representing eight mines in Wyoming were selected. The post-mining shrub component of the vegetation of these sites was dominated by fourwing saltbush (5 sites) or by fourwing saltbush-sagebrush (9 sites), although the seed mixtures that produced the post-mining communities varied. Transects were systematically located across each site and were oriented perpendicular to the length of the site. Shrub density by species was determined. Shrub seedlings, standing-dead shrubs, and shrub height were measured. Degree of browsing was also noted. Total shrub densities, canopy cover, and shrub density by species was calculated. Diversity indices were also calculated using the shrub density data. Antelope and sage grouse habitat requirements were used to assess wildlife habitat quality of the shrub communities evaluated.

Total shrub densities were nearly 3 times greater on the saltbush-sagebrush sites compared to the fourwing saltbush sites. When extrapolating the newly established shrub density requirement of 1 shrub/m^2 on 20% of the land area to 100% of the land area, the shrub density can be assumed to be 0.2 shrubs/m^2. On this basis, only one of the five saltbush communities and seven of the nine saltbush-sagebrush communities had shrub densities greater than the 0.2 shrubs/m^2. While this extrapolation provides a means of comparing the pre-1985 reclamation plantings to the new standard, we recognize its limitations. It ignores the current requirement of

shrub patch spatial diversity. If you evaluate the survey sites as a patch of mature shrubs and compare these densities to the standard, none of the sites would meet the new shrub density standard.

Shrub densities on saltbush-sagebrush sites were closely correlated to total shrub seeding rates. No correlation was found between seeding rates and shrub density among the saltbush sites. Grass seeding rates on all sites ranged from 15 to 29 kg PLS/ha and this level of competition did not have an effect on shrub density. This finding agrees with that observed in the Establishment Study where the only difference in sagebrush establishment occurred between no grass competition and when grass was seeded. Natural immigration of shrubs was also limited and only occurred in areas adjacent to established shrub communities. Therefore, significant natural immigration will likely require several decades unless the reclamation site is overseeded with shrub species to speed up the process.

Evaluation of the survey study data in terms of wildlife habitat resulted in several interesting and important findings. When comparing published shrub cover requirements for antelope to those measured on the reclaimed sites, only two of the saltbush sites and four of the saltbush-sagebrush sites provided marginal to adequate cover. Cover needs for sage grouse were only met at one saltbush site and at four saltbush-sagebrush sites. The present shrub reclamation guidelines in Wyoming focus solely on shrub density, rather than on cover, to assess reclamation success. These findings indicate that cover is equally important to shrub density when evaluating reclaimed lands for wildlife habitat. When evaluating sagebrush height, five of the nine saltbush-sagebrush sites and only one of the saltbush sites had heights great enough to fall within requirements established for antelope. Sage grouse sagebrush height requirements for nesting habitat were met a one saltbush site and at seven of the nine saltbush-sagebrush sites.

Diversity indices were three times higher on saltbush-sagebrush sites compared to the saltbush sites.

The data indicate that the more shrub species included in the original seed mixture the greater the overall shrub density and diversity. Several of the saltbush-sagebrush sites displayed encouraging signs of increased shrub densities by the presence of age stratified populations. Sites with more shrub species in the initial seed mixture more closely resemble the diversity of the pre-mine community and are more likely to have the highly desired characteristics necessary for optimum wildlife habitat.

Summary

Establishment of Wyoming big sagebrush on mined lands in Wyoming can be enhanced by the improved understanding of seedbed ecology and environmental factors that were evaluated by this research. Mulch, removing herbaceous competition, and direct-placed topsoil (Establishment Study) improved sagebrush seedling establishment and survival. The densities of sagebrush seedlings established met the density requirements of the new Wyoming shrub standard, which indicates that the standard is achievable under the conditions encountered during the study period. The research has also clearly shown that sagebrush seed will remain viable for at least 3 years after seeding, which enables seed germination to occur over a period of several years and varying climatic conditions. The use of fourwing saltbush as a pioneer species to improve sagebrush recruitment did not show any increase in sagebrush establishment nor did it

result in any reduction in sagebrush establishment. However, it did result in increased total shrub density and cover, further supporting the importance of including multiple shrub species in the seed mixture.

Our survey of fourteen pre-1985 reclamation sites in Wyoming showed that greater shrub establishment was achieved when the initial seed mixture included saltbush and sagebrush compared to when only saltbush was in the mixture. The fourteen sites did not produce shrub densities that would meet the new Wyoming shrub standard. However, the findings point out the importance of shrub cover in assessing wildlife habitat rather than using only shrub density as a criteria of reclamation success.

Many of the findings reiterate some important and well known facts; however, many of these findings are still not fully accepted by reclamationist and regulatory personnel when developing reclamation plans. Recommendations from this research will result in improved sagebrush establishment on Wyoming mined lands.

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FINAL REPORT

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