

The research has identified cultural practices that can be utilized by reclamationists to enhance shrub establishment and achieve the desired shrub densities under near normal or optimum climatic conditions. Climatic conditions, particularly precipitation and temperature, significantly influence sagebrush germination and seedling establishment; however, the negative effects of environmental stress can be reduced using the cultural practices described.

B. Introduction

Xerophytic shrubs are a conspicuous component of rangelands throughout Wyoming and much of the arid/semiarid West and they provide manifold benefits to the function and utility of rangeland ecosystems (McKell and Goodin 1973). Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) is one of the most widely distributed and adapted shrub species in Wyoming and the region (Beetle and Johnson 1982). However, reestablishment on mined lands has generally proven difficult because of low seedling vigor, an inability to compete with herbaceous species, and altered edaphic conditions (Harniss and McDonough 1976, Young and Evans 1989, Schuman et al. 1998). Reduced levels of arbuscular mycorrhizae in disturbed soils has been postulated as a factor limiting the success of reestablishment of big sagebrush on disturbed lands (Call and McKell 1982, Stahl et al. 1988). This perceived limitation is based on the fact that arbuscular mycorrhizae can improve a host plant's ability to extract nutrients and water from the soil and observations that sagebrush appears to be particularly dependent upon mycorrhizal symbiosis to reach full growth potential (Allen 1984). Indirect evidence also indicates that soil water availability is one of the most critical factors involved in big sagebrush seedling establishment (Jones 1991). The use of "pioneer" plants to prepare reclaimed sites for later seral species has been postulated by Booth (1985) and Meyer (1990). Booth (1985) suggested that fourwing saltbush (*Atriplex canescens*) could function in this role and noted that fourwing saltbush was easily established using conventional seeding methods. Although considerable debate has surrounded sagebrush value and use in mined land reclamation (Tessman and Kleinman 1989, Colbert and Colbert 1983), the fact remains that the Wyoming Department of Environmental Quality, Land Quality Division and the Office of Surface Mining have recently enacted rules to require the reestablishment of shrubs (those species dominant prior to mining) on mined land. The findings of this research will greatly aid in the reestablishment of Wyoming big sagebrush and will enhance the mining industry's ability to meet these new regulations where sagebrush is an important predisturbance shrub species.

C. Research Objectives

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: (1) determine the efficacy of direct-applied topsoil for enhanced sagebrush establishment, (2) determine the value of an annual grain stubble mulch for increasing sagebrush establishment through enhanced moisture conservation and microsite modification as compared to superficially applied straw mulch, (3) determine the effect of competition from concurrently seeded grasses on establishment of big sagebrush, (4) determine the effect of establishing fourwing saltbush as a

pioneer species for later recruitment of sagebrush, (5) determine the effect of AM on moisture stress tolerance of big sagebrush seedlings, and (6) evaluate pre-1985 reclamation methods on shrub establishment.

D. Methods

This project was composed of three field studies and one laboratory/greenhouse study. The field studies are identified as the "Establishment Study," the "Pioneer Plant Study," and the "Survey Study." The Establishment and Pioneer studies were implemented simultaneously at the North Antelope Coal Company mine about 100 km north of Douglas, Wyoming. The field plots were established in August 1990 on approximately 1.2 ha of leveled coal mine spoil. The greenhouse study was conducted at the Plant, Soil, and Insect Sciences Department facilities and the Survey study was conducted at 8 mines throughout Wyoming.

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 herbaceous species competition (two levels of concurrently seeded native grass mixture). Three replicate main plots (15 x 60 m) of each topsoil management treatment were established by replacing 30 cm of either direct-applied or stockpiled topsoil on regraded good quality spoil material. Mulch subplots (15 x 15m) were established on each topsoil management main plot. All treatments were assigned at random in a randomized block, split-split plot design (Figure 1). All plots were ripped and disked to relieve compaction during spoil regrading and topsoil replacement. In late April 1991, 'Steptoe' barley (*Hordium vulgare*) was seeded at the rate of 60 kg/ha on the mulch subplots that had been assigned the stubble or stubble + straw mulch treatments. In mid-July the barley was clipped to reduce seed maturation and subsequent year competition from volunteer barley plants. Annual weeds on the other mulch treatment plots were controlled with 0.55 kg/ha glyphosate [N-(phosphonomethyl) glycine] and tillage.

In late November 1991, the competition treatments were imposed by drill seeding a mixture of 'Rosana' western wheatgrass (*Pascopyrum smithii*), 'San Luis' slender wheatgrass (*Elymus trachycaulus*), and 'Critana' thickspike wheatgrass (*Elymus lanceolatus*) composed of equal seed numbers of each of the grasses. Grass seeding was made as a dormant seeding after soil temperature had dropped below that conducive to germination. The competition sub-subplots were seeded at 0, 16, and 32 kg PLS(pure live seed)/ha. After seeding the grass mixture, wheat (*Triticum aestivum*) straw was added at 1000 kg/ha to the stubble + straw treatment and 4500 kg/ha of straw was applied to the straw mulch treatment sub-subplots and crimped into the soil surface using a vertical disk crimper.

In early March 1992, all plots were broadcast seeded with sagebrush (2.63 kg PLS/ha) without any seed covering. The sagebrush was seeded at this time of year to reduce the potential for spurious germination during the winter if temperatures became adequate and also to reduce the length of time the seed might be displaced by the wind. Rice hulls were mixed with the sagebrush seed to improve seed flow in the seeder. The sagebrush seed was collected in the