NATIVE SHRUB ESTABLISHMENT IN COLORADO[1]

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Abstract. The Colorado Division of Minerals and Geology is sponsoring a study to evaluate native shrub establishment on reclaimed lands. The goal of the study is provide enhanced wildlife habitat after mining. Dr. Ed Redente and Mark Paschke from Colorado State University are conducting the research. The first phase of the study included a comprehensive literature review. The literature review covered the biology, ecology, and propagation of seven species that are of primary importance for wildlife habitat in Colorado.

Two main limitations to shrub establishment at the Colorado reclaimed mines are browsing and competition from aggressive herbaceous species. The second phase of the project involved a field study to evaluate reclamation techniques to overcome these obstacles. The experimental design used large-scale demonstration plots that were constructed with normal reclamation equipment to test shrub establishment techniques that have commercial practicality. Plots were established at three coal mines in northwestern Colorado. Several treatments are being tested to evaluate shrub establishment on spoil material, 6 inches of topsoil, and 18 inches of topsoil. Plots were strip seeded with native seed mixes, alternating rows of herbaceous species and shrub species. Native shrub transplants were planted at one mine. Half of each treatment was fenced to prevent browsing. Plots were installed in 2000. Soil samples at all plots were collected in April 2001. The first year's data was collected in July 2001. Preliminary results indicate topsoil and spoil at all mine sites have favorable characteristics for plant growth. Fall seeding at Colowyo resulted in establishment of most of the seeded species but weedy annuals dominated plots during this first growing season. Fall seeding and shrub transplanting at Seneca II mine appears to have been successful but the plots are also dominated by annuals. Spring seeding at Trapper resulted in very poor establishment. More time will be needed to make a suitable evaluation of these treatments.

Additional Key Words: Wildlife habitat, native seed mixes, fall seeding, spring seeding, topsoil depth.

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Introduction

Colorado coal mines are located in prime wildlife habitat. Sagebrush grasslands provide winter range, breeding and nesting habitat for sage grouse and Columbian sharp-tailed grouse. Mixed mountain shrub communities provide winter range and fawning and calving grounds for deer and elk. Big game is concentrated in mountain shrublands during winter periods and the quality of the mountain shrub habitat is the key determinant of the carrying capacity for big game population in Colorado (Wallmo et al. 1976). Despite the wide diversity of mountain shrub habitat types, there are relatively few dominant shrub species found in this vegetation type. Notable among these common shrubs are big sagebrush (*Artemisia tridentata*), antelope bitterbrush (*Purshia tridentata*), mountain mahogany (*Cercocarpus montanus*), Gambel oak (*Quercus gambelii*), Saskatoon serviceberry (*Amelanchier alnifolia*), black chokecherry (*Prunus virginiana melanocarpa*), snowberry (*Symphoricarpos sp.)*, rabbitbrush (*Chrysothamnus* sp.), rose (*Rosa* sp.), willow (*Salix* sp.), and saltbush (*Atriplex* sp.) (Terwilliger 1978, Tiedeman and Terwilliger 1978, Hoffmann 1979, Hoffman and Alexander 1980, Hess 1982, Hoffman and Alexander 1983, Alexander 1985, Hess and Alexander 1986, Alexander 1987, Banner 1992, Colorado Natural Areas Program 1998).

In the majority of the Colorado coal mine permits, wildlife habitat is either the primary or secondary post mining land use. Reclamation plans are designed to restore habitat for wildlife species. The Colorado Division of Minerals and Geology (DMG), in cooperation with the Division of Wildlife (DOW) and coal mine operators, has and continues to evaluate reclamation techniques that will promote wildlife habitat.

Over the years coal operators have made many attempts to reestablish the native shrubs that dominate a majority of the mined lands in western Colorado. These techniques included transplanting mature shrub islands at the Eckman Park and Trapper Mines, transplanting small shrub tubelings at the Seneca Mines, strip seeding rows of shrub seed between the reclamation mix at the Eckman Park Mine and live handling topsoil with no seed at the Eckman Park Mine.

The results of these attempts were inconsistent and variable. Native shrub island transplants are successful at the Trapper Mine, but not at the Eckman Park Mine. Transplanted tubelings have been successful at the Seneca Mines, but not at other coal mines. Strip seeding was very successful in one area at Eckman Park, but marginally successful in other areas of the mine.

Shrub establishment in live handled topsoil where no seed was planted has been very successful in one area at the Eckman Park Mine and not successful at others. Documentation provided by the operators regarding the methods and results from shrub establishment attempts have been sparse and inconclusive.

Other observed obstacles to shrub establishment at these mines are herbaceous competition and wildlife browsing. Herbaceous competition is primarily from introduced cool season grass species. These species, commonly used in reclamation efforts, are reliable and provide quick erosion control. The uniform replacement of topsoil, at depths ranging from 40-50 cm, is another factor contributing to the homogenous grass community structure. Grasses thrive often at the expense of forb and shrub species. The young shrub plants that do get established are highly desirable browse for deer and elk. Heavy browse pressure creates another obstacle for shrub establishment.

In an attempt to better understand and document native shrub establishment on reclaimed lands, the DMG requested funding to evaluate shrub establishment techniques. Funds were appropriated from the State Severance tax. DMG signed an agreement with Colorado State University (CSU) to conduct the research with Dr. Ed Redente and Dr. Mark Paschke as the lead researchers. The project was divided into two phases. Phase I included a comprehensive literature review on the shrub species of interest and development of a study design. Phase II is a field study using demonstration plots.

Phase I

The literature review in Phase I covered the biology, ecology, and propagation of seven species that are of primary importance for wildlife habitat in Colorado. These are: Antelope bitterbrush, Big sagebrush, Chokecherry, Mountain mahogany, Serviceberry, Snowberry, and Gambel's oak. Dr. Mark Pashcke compiled a comprehensive review evaluating the biology, ecology, and propagation of seven species that are of primary importance for wildlife habitat in Colorado. Four general conclusions were derived from the literature review. They were that successful establishment of these species has most often involved: 1) strategies for avoiding herbaceous competitors, 2) protection from browsing during the establishment phase, 3)

utilization of local shrub ecotypes, varieties or subspecies in reclamation efforts, and 4) providing a source of mutualistic soil organisms (Paschke 2001).

During Phase I representatives of the DMG, the Colorado Division of Wildlife (DOW), CSU researchers and mining companies toured several mines to observe the different shrub establishment techniques that had been attempted. Based on the results of the literature review, the field visits, professional observations and several meetings amongst all parties, a field study was developed.

Phase II

Site Description

The mines that volunteered to participate in the field study are all large surface mines in northwestern Colorado: the Colowyo Mine, the Seneca Mine, and the Trapper Mine. Permit areas range from 3500 acres at Seneca to 10,400 acres at Trapper. All three mines are in dense mountain shrublands that provide valuable wildlife habitat. The mines collectively have made many attempts at shrub establishment on their reclaimed lands and they are interested in developing techniques that will have higher levels of success.

Elevations range from 1982 m at Colowyo and Trapper to 2470 m at Seneca No. 2. Geology is characterized by interbedded shales, sandstones, sandy shales and coals. Primarily ephemeral and intermittent streams drain the permit areas. The region has a highland continental climate characterized by low precipitation, large fluctuations in diurnal temperatures, low humidity, moderate wind and high levels of insolation (exposure to sunlight). Local climate is characteristic of semi-arid steppe regions with average precipitation ranging from 34 cm at Colowyo to 48 cm at Seneca. Soils are typical of soils found in cold, semi-arid regions of the western United States. They are moderately deep (50-102 cm) to shallow (15-50 cm). Soils were developed in weathered, interbedded fine sandstone, siltstone and shale, and in local slopewash and colluvium. The dominant vegetation types are sagebrush grasslands and mountain shrublands. Sagebrush is common on the colluvial toe-slopes. The north facing hillslopes and higher elevations are dominated by well-developed mountain shrub communities. Current and historic land uses in the vicinity of these operations has been grazing for livestock, and wildlife habitat. Herds of mule deer and elk are common, especially on reclaimed areas

during the winter. Known elk calving areas are scattered throughout these permit areas. Common raptors are the Golden Eagle, Red-tailed hawk, Great horned owl, Marsh hawk and American kestrel. Blue grouse, sharptail grouse and sage grouse are all residents or occasional residents in this area.

Methods

The experimental approach utilized large-scale demonstration plots constructed with standard reclamation equipment to test shrub establishment techniques that have commercial practicality. This approach was selected instead of exact replications to allow each mine to use their available resources. Each mine provided the equipment, plant materials, and fencing supplies for plot construction. The treatments used in the field study were designed to incorporate the findings of the Phase I literature review, and to overcome the two primary field observed obstacles to shrub establishment (competition from aggressive herbaceous species and browsing). Plots were constructed in the fall of 2000. Figures 1-3 show the layout of the plots at each mine.

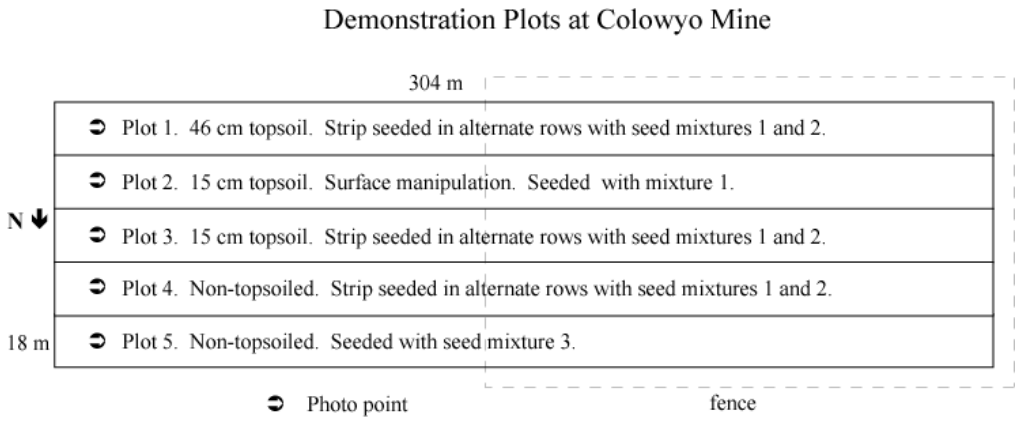

Figure 1. Shrub establishment demonstration plots at Colowyo mine.

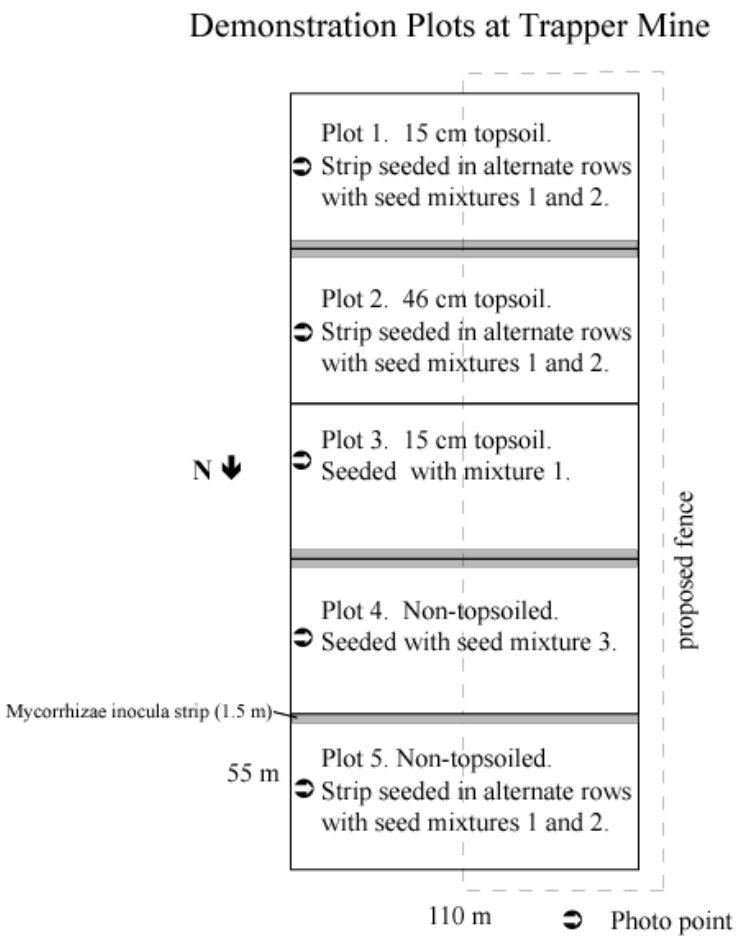

Figure 2. Shrub establishment demonstration plots at Trapper mine.

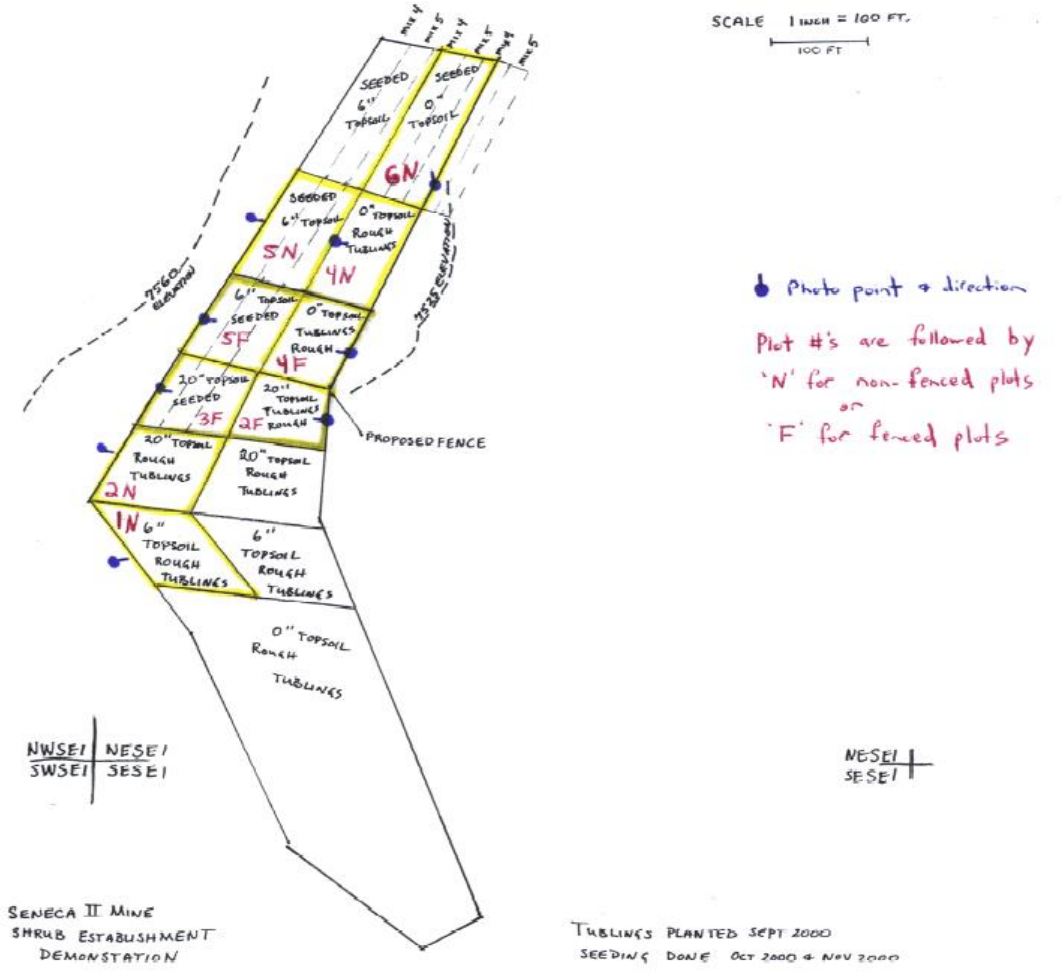

Figure 3. Shrub establishment demonstration plots at Seneca II mine.

Seed mixes were developed for each mine using their approved seed mix as a foundation. The mixes were carefully evaluated to eliminate the competitive introduced species and to reduce the total percentage of grass seeded. At Colowyo and Trapper several plots were strip seeded using the seed mixes in Tables 1 and 2. Strip seeding
using a rangeland drill isolated the shrub and forb species to further reduce competition from grass species. A strip is equal to one drill width. Small seeded species such as sagebrush and rabbitbrush were broadcast seeded. The seed mixes used at Seneca are presented on Tables 4 and 5. These were strip seeded. The plots at the Colowyo Mine and the Seneca Mine were seeded in September 2000. The Trapper Mine plots were initially planted in May 2001 and reseeded in October 2001.

A total of 9,300 tubelings were planted on several plots at the Seneca Mine. The plant materials were one-year-old containerized nursery stock developed from bitterbrush, chokecherry, Gambel oak, serviceberry, snowberry, Woods rose and boxelder seed collected from the Seneca II mine site. The seedlings were grown and planted by Bitterroot Native Growers, Inc. Tree Guard browse repellant was placed on all planted seedlings. All seedlings were treated with a mychorrhizal fungi inoculum that was developed at the Bitterroot nursery (Seneca 2001).

The depth of topsoil on the plots was varied to evaluate shrub and forb response to topsoil depths ranging from 0 cm to 46 cm. At Trapper, a 1.5 m strip of mychorrhizae inocula, EndoNet, donated by BioNet, LLC, was applied between treatments. Stockpiled topsoil was used at the Seneca and Trapper plots; live handled topsoil was used at Colowyo. Soil samples from all plots were taken in April, 2001.

Two treatments were designed to evaluate browsing on the plots. First, a non-palatable seed mix, Table 3, was developed using common shrubs in the mixed shrublands, but not choice browse species. This seed mix was drill seeded on one plot at Trapper and Colowyo. Second, one half of each demonstration plot was fenced to provide a grazed, non-grazed comparison. Heavy duty fencing was constructed to exclude deer and elk.

Surface roughening using a dozer to create depressions was included as a treatment on one plot at Colowyo and Trapper. Surface roughening was used on half of the Seneca plots due to the steep slopes. Not only will the roughened surface help with erosion control, but also the depressions create a microhabitat that may enhance shrub establishment.

Preliminary Results

Composite soil samples taken from each treatment at each mine were analyzed in April 2001. Overall, the soils (topsoil and spoil) at all three mine sites have good physical and chemical properties. Soil pH ranges from 6.9 to 7.8, macronutrients appear to be adequate for sustained plant growth, organic matter contents are relatively high (3.7% to 6.3%), salt levels are low (EC ranges from 0.6 to 1.6 mmhos/cm and SAR ranges from 0.3 to 1.8), cation exchange capacity (CEC) is in a normal range, and textures are clay loam and sandy clay loam. A potential

deficiency was apparent at Trapper and Seneca where phosphorus levels range from 0.2 to 4.3 mg/kg, below the 7mg/kg level considered to be adequate for plant growth.

Little variation was observed between topsoil and spoil materials with a few exceptions. At Colowyo potassium levels were substantially lower in the spoil. At Trapper, pH is slightly higher in the spoil and NO_3-N levels are higher in the topsoil. Phosphorus and potassium levels are both substantially lower in the spoil. At Seneca, phosphorus levels and pH are lower in the spoil.

Overall, topsoil and spoil at all mine sites have favorable characteristics for plant growth, with the possible exception of phosphorus at Trapper and Seneca. However, plant growth from previous reclamation efforts has not shown evidence of phosphorus deficiencies and we can assume at this time that phosphorus levels are adequate. As a precaution, however, inspections for visual symptoms of phosphorus deficiency (purple leaf coloration) will be made during future vegetation monitoring.

Vegetation Sampling

In July 2001, vegetation sampling was conducted at all three mines. Each demonstration plot was sampled for vegetative cover by species, bare ground, rock and litter. A point-intercept method was used to estimate cover. Within each plot at Colowyo and Trapper (Figures 1 and 2), five 100-m transects were randomly located. One of the five transects in each plot at Trapper mine was stratified in mycorrhizae inoculation strips in order to document baseline conditions in these subplots. Cover data was collected every one meter along each transect (500 cover points per plot). At the Seneca II mine, where plots are considerably smaller (Figure 3), three 30-m transects were used and cover data was collected every one meter (90 cover points per plot). Some plots at the Seneca II mine were divided into subplots by a fence. During the July 2001 vegetation sampling both subplots (fenced and unfenced) were sampled. Plots at the Colowyo mine were also subdivided by a fence treatment, but the fence was not constructed until after sampling, therefore we did not stratify our sampling by fence treatment. Fence construction at Trapper mine will be completed prior to the 2002 vegetation sampling.

In addition to cover sampling along these transects, shrub establishment and shrub height was estimated in each demonstration plot within small quadrants along each transect. At Colowyo and Trapper, the quadrants were $0.25m^2$ and were located every 20 m along the transect for a

total of 6.25 m^2 per plot. In the smaller plots at Seneca II mine, 0.5m^2 quadrants were located every 10 m along each transect for a total sampling area of 4.5 m^2 per demonstration plot. Within each of these quadrants all shrubs were identified by species and heights of individuals were recorded.

To evaluate the success of the shrub tubelings at Seneca, survival of transplants was quantified during the vegetation sampling. Shrub survival within each demonstration plot was estimated by following rows of transplants and scoring seedlings as either alive or dead. A minimum of 25% of the transplant rows within each plot was surveyed as such.

Preliminary results from the Colowyo Mine show most of the seeded species were present on the plots. Lewis flax and mountain brome are two seeded species that were showing relatively high cover during the first growing season, especially in topsoiled plots. Early successional weedy annual species such as field pennycress were also well established, especially in the plot with 46 cm topsoil. The non-topsoiled plots at Colowyo had much lower vegetative cover and fewer plant taxa than the topsoiled plots. This difference results largely from the higher cover of weedy species on the topsoiled plots. Shrub species were establishing well in the plots at Colowyo. Mountain big sagebrush appears to have established well in most plots relative to other shrub species. Shrub density was lowest in the plot 5 seeded with the unpalatable seed mix. Of the 11 shrub species that were seeded at Colowyo, 9 were encountered in the vegetation surveys Silver buffaloberry and Wood's rose, part of the unpalatable seed mix planted in one plot, were not found.

Most of the vegetative cover in demonstration plots at Trapper was attributed to Russian thistle, an annual invasive species. No shrubs were found in the shrub density and height surveys. However, a few widely scattered shrub seedlings were observed in the plots. Three planted species were observed in the plots at less than 1 percent cover. Dry conditions after the spring 2001 seeding operation may have contributed to the lack of success. Because, Trapper generally seeds in the fall and has much better germination success they reseeded in the fall of 2001.

With the higher elevation of Seneca II, early results are less evident at the time of sampling relative to Colowyo. Four of the seeded species were encountered in some of the plots at Seneca II. Like Colowyo and Trapper, Russian thistle dominated topsoiled plots at Seneca II. Shrub density was low at Seneca II relative to Colowyo. However, two seeded species appeared to be

establishing during this early phase of the study. All species of planted shrub tubelings showed good survival at the time of sampling.

These preliminary results indicate that the spring seeding at Trapper mine was not successful. Fall seeding at Colowyo resulted in establishment of most of the seeded species but weedy annuals dominated plots during this first growing season. Fall seeding and shrub transplanting at Seneca II mine appears to have been somewhat successful but more time will be needed to make a suitable evaluation.

Monitoring for this project is scheduled to continue for four more years. It has been our experience that after three years in mine reclamation that the annual species die out and the characteristics of the long term community are established. After that time we will have a better sense of what reclamation techniques are most successful in establishing native shrubs.

Table 1. Native shrub and forb seed mixture for demonstration plots at Colowyo and Trapper Mines.

SCIENTIFIC NAME	COMMON NAME	SEED RATE LBS PLS/A	PLS/SQFT
Shrubs*	**Shrubs**		
Purshia tridentate	Antelope bitterbrush	5.0	1.7
Artemisia cana	Silver sagebrush	0.20	3.9
Artemisia tridentata vaseyana	Big sagebrush	0.25	14.3
Prunus virginiana	Chokecherry	4.0	0.4
Chrysothamnus nauseosus	Big rabbitbrush	0.5	4.6
Amelanchier alnifolia	Serviceberry	1.0	0.6
Symphoricarpos oreophilus	Snowberry	3.0	5.2
Rosa woodsii	Woods rose	2.0	2.1
Forbs	**Forbs**		
Linum lewisii	Lewis flax	1.0	6.7
Penstemon palmeri	Palmer penstemon	0.5	7.0
Penstemon strictus	Rocky Mountain penstemon	0.5	6.8
Balsamhoriza sagittata	Arrowleaf balsamroot	0.5	0.6
Achillea lanulosa	Western yarrow	0.1	6.4
Aster chilensis	Pacific aster	0.1	6.1
TOTAL		18.55	66.5

Table 2. Native grass, forb, and shrub seed mixture for demonstration plots at Colowyo and Trapper Mines.

SCIENTIFIC NAME	COMMON NAME	SEEDING RATE IN LBS PLS/A	PLS/SQFT
Grasses	**Grasses**		
Agropyron spicatum	Bluebunch wheatgrass	1.0	3.2
Festuca ovina	Sheep fescue	0.5	7.8
Bromus marginatus	Mountain brome	1.0	2.1
			13.1
Forbs	**Forbs**		
Linum lewisii	Lewis flax	1.0	6.7
Penstemon palmeri	Palmer penstemon	0.5	7.0
Penstemon strictus	Rocky Mountain penstemon	0.5	6.8
Balsamhoriza sagittata	Arrowleaf balsamroot	0.5	0.6
Achillea lanulosa	Western yarrow	0.1	6.4
			6.1
Shrubs*	**Shrubs**		
Purshia tridentata	Antelope bitterbrush	5.0	1.7
Artemisia cana	Silver sagebrush	0.2	3.9
Artemisia tridentata vaseyana	Big sagebrush	0.25	14.3
Prunus virginiana	Chokecherry	4.0	0.4
Chrysothamnus nauseosus	Big rabbitbrush	0.5	4.6
Amelanchier alnifolia	Serviceberry	1.0	0.6
Symphoricarpos oreophilus	Snowberry	3.0	5.2
Rosa woodsii	Woods rose	2.0	2.1
TOTAL		21.05	79.6

Table 3. Seed mixture of unpalatable native shrubs and low-competitive native grasses and forbs for demonstration plots at Colowyo and Trapper Mines.

SCIENTIFIC NAME	COMMON NAME	SEEDING RATE IN LBS PLS/A	PLS/SQFT
Shrubs*	**Shrubs**		
Chrysothamnus nauseosus	Big rabbitbrush	1.0	9.2
Chrysothamnus viscidiflorus	Douglas rabbitbrush	1.0	18.0
Rosa woodsii	Woods rose	3.0	3.1
Artemisia cana	Silver sagebrush	0.20	3.9
Artemisia tridentata vaseyana	Big sagebrush	0.50	14.3
Shepherdia argentea	Silver buffaloberry	3.0	3.1
Rhus trilobata	Skunkbush sumac	3.0	1.4
Forbs	**Forbs**		
Linum lewisii	Lewis flax	1.0	6.7
Penstemon palmeri	Palmer penstemon	0.5	7.0
Penstemon strictus	Rocky Mountain penstemon	0.5	6.8
Balsamhoriza sagittata	Arrowleaf balsamroot	0.5	0.6
Achillea lanulosa	Western yarrow	0.1	6.4
			6.1
Grasses	**Grasses**		
Agropyron spicatum	Bluebunch wheatgrass	1.0	3.2
Festuca ovina	Sheep fescue	0.5	7.8
Bromus marginatus	Mountain brome	1.0	2.1
Agropyron trachycaulum	Slender wheatgrass	1.0	3.7
TOTAL		17.80	103.4

Table 4. Native grass, forb, & shrub seed mixture for demonstration plots at the Seneca Mine.

SCIENTIFIC NAME	COMMON NAME	SEEDING RATE IN LBS PLS/A	PLS/SQFT
Grasses	**Grasses**		
Agropyron spicatum	Bluebunch wheatgrass	1.0	3.2
Bromus marginatus	Mountain brome	1.0	2.1
Agropyron trachycaulum	Slender wheatgrass	1.0	3.7
Poa ampla	Big bluegrass	1.0	20.2
Forbs	**Forbs**		
Balsamorhiza sagittata	Arrowleaf balsamroot	1.0	1.3
Lupinus alpestris	Mountain lupine	1.0	0.6
Linum lewisii	Lewis flax	1.0	6.7
Penstemon palmeri	Palmer penstemon	0.5	7.0
Penstemon strictus	Rocky Mountain penstemon	0.5	6.8
Shrubs	**Shrubs**		
Purshia tridentata	Antelope bitterbrush	3.0	1.0
Amelanchier utahensis	Serviceberry	3.0	1.8
Symphoricarpos albus	Snowberry	3.0	5.2
Rosa woodsii	Woods rose	2.0	2.1
Prunus virginiana	Chokecherry	4.0	0.4
TOTAL		25.0	62.1

Table 5. Native shrub and forb seed mixture for demonstration plots at the Seneca Mine.

SCIENTIFIC NAME	COMMON NAME	SEEDING RATE IN LBS PLS/A	PLS/SQFT
Shrubs	**Shrubs**		
Purshia tridentata	Antelope bitterbrush	3.0	1.0
Amelanchier utahensis or *alnifolia*	Serviceberry	3.0	1.8
Symphoricarpos oreophilus	Snowberry	3.0	5.2
Rosa woodsii	Woods rose	2.0	2.1
Prunus virginiana	Chokecherry	4.0	0.4
Forbs	**Forbs**		
Balsamorhiza sagittata	Arrowleaf balsamroot	1.0	1.3
Lupinus alpestris	Mountain lupine	1.0	0.6
Linum lewisii	Lewis flax	1.0	6.7
Penstemon palmeri	Palmer penstemon	0.5	7.0
Penstemon strictus	Rocky Mountain penstemon	0.5	6.8
TOTAL		21.0	32.9

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