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SURFACE REHABILITATION OF LAND DISTURBANCES RESULTING FROM OIL SHALE DEVELOPMENT

Final Report
December 31, 1974
Phase II

Colorado State University
Fort Collins, Colorado

SURFACE REHABILITATION OF LAND DISTURBANCES
RESULTING FROM OIL SHALE DEVELOPMENT

Final Report, Phase II

December 31, 1974

to the

COLORADO DEPARTMENT OF NATURAL RESOURCES

Thomas W. Ten Eyck, Executive Director

under terms of

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Assembled by

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Ft. Collins, Colorado

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VEGETATIVE STABILIZATION OF SPENT OIL SHALES

(FIELD RESEARCH)

Piceance Basin study site, August 1974.

H. P. HARBERT AND W. A. BERG

DEPARTMENT OF AGRONOMY

FINDINGS

1. In this study the bulk of the soluble salts in spent oil shales were leached to depths of several feet, however, the fine-textured spent shale was later resalinized by salt dissolved in water moving upward by capillary rise.
2. Six inches of soil cover over the leached fine-textured spent shale was also salinized.
3. The coarser-textured spent shale became resalinized at one site but not at the other. These differences are apparently due to the efficiency of the leaching procedures and possibly on the degree of compaction of the spent shale.
4. Twelve inches of soil cover over unleached spent shales was not salinized. It is believed that the salt did not move upward in these treatments because the water content of the spent shale was lower than in the leached treatment.
5. Surface temperatures on the south-facing slope of the fine-textured spent shale were cooler in the spring and much warmer in the summer than on soil. Mid-summer surface temperatures of 150° F were recorded on the fine-textured spent shale.
6. Resalinization was greater on south-facing slopes than on north-facing slopes.
7. A good cover of native species was established with intensive management on all spent shale and soil cover treatments at one study site. An adequate vegetative cover must still be established at the other site.
8. Effects of the salinity and high surface temperatures are noticeable on the vegetation and with time are expected to become more pronounced.

9. Barley plants growing in both spent shales had higher molybdenum and zinc contents than plants growing in soil.
10. Runoff from a small storm was greater from the fine-textured spent shale than from the coarse spent shale or soil.

RECOMMENDATIONS

1. If spent shales are to be used as a plant growth media they will need to be more intensively leached and managed than the plots in this study. Soil cover appears to be a more feasible approach.
2. Six inches of soil cover over leached fine-textured spent shale became salinized, twelve inches of soil cover over unleached spent shales did not. Research is needed on depths of soil cover over spent shales of various textures.
3. South and southwest facing slopes should be avoided if possible in development of spent shale disposal areas at the lower and middle elevations of the Colorado oil shale region.

INTRODUCTION

Disposal of massive amounts of spent shale will be required if an oil shale industry using surface retorting is developed. Some of the spent shale may be returned to mined-out areas; however, large amounts of spent shale would probably be disposed of by compacting it into canyons. The surface of these piles might be stabilized by establishment of vegetation directly on the spent shale or on soil cover over the spent shale.

Spent shales are too salty for plant growth and very deficient in plant available nitrogen (N) and phosphorus (P). Good stands of vegetation have been established on TOSCO spent shale after leaching, fertilization and sprinkling for seedling establishment.[1] The unanswered question on the TOSCO spent shale is: Can adequate vegetative cover, to control erosion, be maintained under natural precipitation conditions once the stand has been established by intensive management practices?

Little or no information is available on characteristics, as a plant growth media, of spent shale produced by other retorting methods. However, it is known that some processes use higher temperatures which would mean greater alkalinity (pH). Also other processes require air flow through the retort. This requires coarser feedstock than the TOSCO process and results in a considerably coarser spent shale. Thus, the suitability of spent shale as a plant growth media would depend on the physical and chemical characteristics which are, in part, a function of the retorting process. These factors plus the on-site factors of climate, aspect, elevation, slope, and management determine the potential plant cover.

With these factors in mind, this study was designed with the primary objectives of investigating surface stability of, and salt movement in, spent shales and spent shales covered with soil after vegetation had been established by intensive treatment, and then left under natural precipitation conditions. A secondary objective is to evaluate the establishment and growth of various native plant species seeded in spent shales and soil cover over spent shales.

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[1] Processed Shale Revegetation Studies, 1965-1972. M. B. Bloch and P. D. Kilborn, editors, Colony Development Operation, Atlantic Richfield Company, Operator, April 1973.

STUDY DESIGN AND METHODS

The spent shales used were from processes developed by The Oil Shale Corporation (TOSCO), and the U. S. Bureau of Mines (USBM). The TOSCO spent shale is a uniformly fine-textured (silt loam) black material[1] retorted at the Colony Development Operation near Grand Valley, Colorado. The USBM spent shale was from the waste pile at the USBM Anvil Points facility. The USBM spent shale is gray to black and contains about 60 percent coarse particles (>2mm diameter) and 40 percent soil-size particles which are a loam in texture.[1]

The basic study design consists of two sets of plots: one set at 5,700 feet (Anvil Points site) and the other at 7,300 feet (Piceance Basin site). The following seven "soil-spent shale" treatments were tested.

1. Leached TOSCO spent shale.
2. Leached TOSCO spent shale with 6 inches of soil cover.
3. Unleached TOSCO spent shale with 12 inches of soil cover.
4. Leached USBM spent shale.
5. Leached USBM spent shale with 6 inches of soil cover.
6. Unleached USBM spent shale with 12 or 24 inches of soil cover.
7. Soil control.

Each treatment has a north and a south exposure on a 4:1 (25%) slope and is replicated (Fig. 1). Thus, there are a total of 28 individual 11 feet wide by 22 feet long plots at each site.

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[1] A literature review on these spent shales is contained in the following: Striffler, W. D., I. F. Wymore and W. A. Berg. 1974. Characteristics of spent shale which influence water quality, sedimentation and plant growth medium. *In* Surface rehabilitation of land disturbances resulting from oil shale development. Colo. State U. Environmental Resources Center Technical Report Series 1.

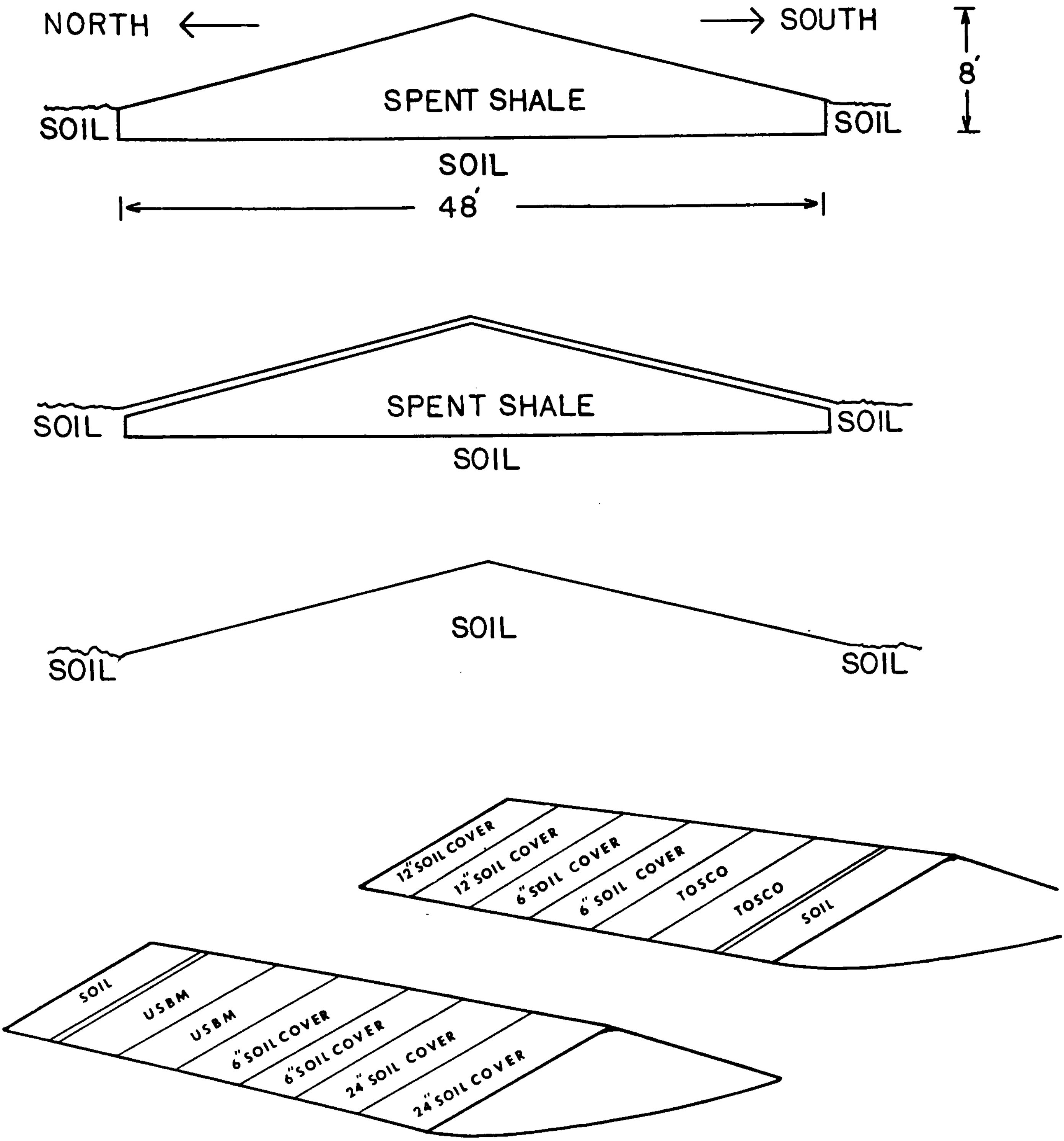

Figure 1. Schematic of spent shale and soil-covered spent shale plots. Top - Side view of cross section through plots. Bottom - Overview of north aspect of TOSCO (upper) and USBM (lower) spent shale plots showing treatments and replications.

With a hot dry summer climate and sparse natural vegetation, the Anvil Points site represents one of the more difficult areas to revegetate within the oil shale region. The average annual precipitation is about 12 inches. The surrounding natural vegetation is the low elevation pinyon-juniper woodlands as described by Ward et al.[1] This site is located on the northwest corner of the housing area of the U. S. Bureau of Mines Oil Shale Research Facility, 8 miles west of Rifle.

The Piceance Basin study site has an average annual precipitation of about 17 inches, and the natural vegetation types are high elevation big sagebrush shrubland, and high elevation pinyon-juniper woodland. This site was selected because its climate, elevation, and vegetation is representative of the federal oil shale lease sites (Colorado a&b) located within the Piceance Basin. The study site is located on federal land (BLM) along Wagonroad Ridge. Access to the site is up Black Sulfur Creek (7 miles) to the Equity Oil Company field camp, then turning right and following the road (2 miles) to the top of the ridge next to the Equity Oil Company radio repeater tower. The plots are across a small valley on a sagebrush flat about 1/2 mile west of the repeater station (SE1/4, NE1/4, S30, T2S, R98W).

The development of both study sites was carried out in five phases:

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[1] Ward, R. T., W. Slauson, R. L. Dix, 1974: Natural Vegetation in the Landscape of the Colorado Oil Shale Region pp 30-66. In Surface Rehabilitation of Land Disturbances Resulting from Oil Shale Development, Colorado State University Environment Resources Center Technical Report Series No. 1.

1. Construction of spent shale piles, soil covering certain treatments, and application of phosphorus fertilizer.
2. Installation of salinity and moisture monitoring equipment within each plot.
3. Leaching of soluble salts by sprinkler irrigation.
4. Installation of individual runoff plots and runoff collection systems.
5. Seeding, mulching, sprinkler irrigation for establishment of seedlings, fertilization with nitrogen, and construction of a deer-proof fence.

The construction phase for each site started with the excavation of 2 feet of soil in an area 48 feet wide and 66 feet long and then filling the center of the excavation with spent shale to a depth of 6-8 feet depending upon the depth of soil cover. The sites were then sloped to 25% and the excavated soil was used for the soil cover treatments. Construction of the plots was completed in April 1973 on the Anvil Points site, and in August 1973 on the Piceance Basin site.

Following construction, each plot was fertilized with triple super phosphate at the rate of 400 pounds P per acre. Each plot was then instrumented with a neutron probe access tube for moisture determinations and two salinity sensors. The access tubes were installed to a depth of 5 feet, and the salinity sensors were buried at depths of 7 and 20 inches.

The spent shale leaching at Anvil Points consisted of applying a total of 40 inches of water by sprinkling (.16 in/hr) for two 5-day periods in May 1973.

The Piceance Basin site was leached with 20 inches of water during August and September 1973, and was leached again the following June with an additional 40 inches of water. A low application rate (.16 in/hr) automated sprinkler irrigation system was used; this applied approximately 1 inch in the 6 hours of the day the system was in operation. However, there was some variation in daily application rates because of the logistics of hauling water to the site.

Runoff plot dividers and catchment containers were completed in April 1974 at Anvil Points and in July 1974 at the Piceance site. A sheet-metal collector and steel culvert catchment container is shown in Fig. 2. The catchment container has a concrete bottom and serves as an overflow container in case the 32 gallon plastic can inside becomes full.

Soil moisture and salinity data were collected at Anvil Points through the growing season in 1973 and 1974, and at Piceance Basin through the 1974 growing season. Soil moisture data collection for both sites consisted of measuring the moisture by depth in each plot with the neutron (soil moisture) probe. Salinity data collection consisted of periodically reading the salinity sensors; however, the sensor is accurate only at high moisture levels. Thus, selected treatments at both sites were core sampled for laboratory salinity measurements in 1973 and 1974. Only the results of the core sampling are given in this report.

Surface temperatures were recorded continuously during the 1973 and 1974 growing season at Anvil Points using Lambrecht 30-day recording thermographs. The sensors were buried approximately 1/4 inch under the surface of the TOSCO spent shale and 6 inches of soil cover

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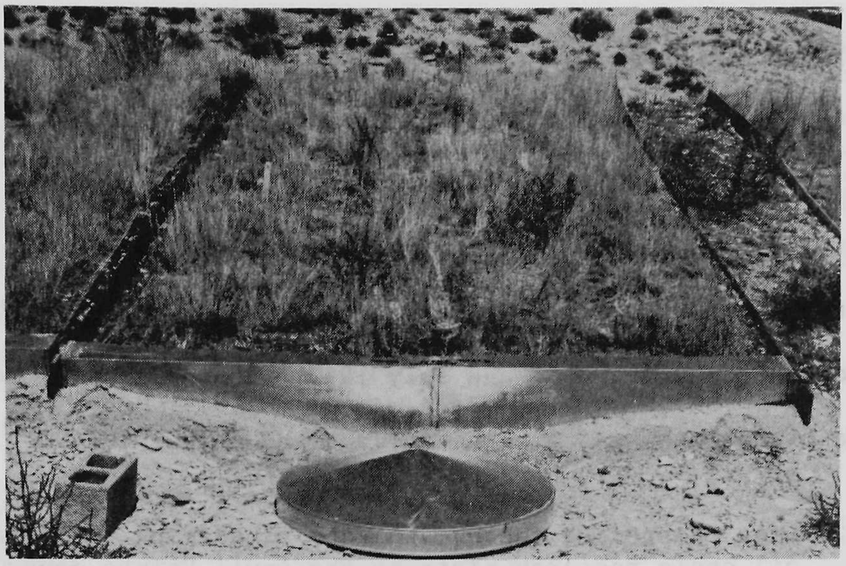


Figure 2. Runoff plot (11' x 22' - 25% slope) with sheet metal collector and 42" diameter x 36" deep catchment basin, with sheet metal lid. (USBM spent shale treatment, south aspect, Anvil Points study site - August, 1974).

Figure 3. Salt crust on TOSCO spent shale treatments south aspect, April 28, 1974, following application of 20 inches of leach water (August, 1973) and 4.5 inches of winter precipitation. (Piceance Basin study site.)

over TOSCO spent shale treatments on both north and south slopes.

The Anvil Points site was seeded on June 11, 1973, with a mixture of native grasses and shrubs (Table 1). The plots were then raked lightly and mulched with hay which was held in place with cotton netting. The plots were sprinkler irrigated with a total of 18.5 inches of water during June and July 1973. In addition, a total of 120 lb/a of nitrogen was applied in June and August 1974.

Table 1. List of species seeded and rate of seeding (lb/a) on the oil shale research plots at the Anvil Points study site, June 11, 1973.

Species	Rate (lb/a)
Grasses	
Bluebunch wheatgrass (*Agropyron spicatum*)	2
Indian ricegrass (*Oryzopsis hymenoides*)	2
Western wheatgrass (*Agropyron smithii*)	1
Shrubs	
Big sagebrush (*Artemisia tridentata*)	1/2
Fourwing saltbush (*Atriplex canescens*)	1
Rabbitbrush (*Chrysothamnus* spp.)	1/2
Winterfat (*Eurotia lanata*)	1

The Piceance Basin plots were seeded on June 26, 1974, with a mixture of species (Table 2), raked lightly and then mulched with straw held in place with cotton netting. These plots were sprinkler irrigated until July 19. A total of 11.0 inches of water was applied for establishment. Following germination, 80 lb/a of nitrogen was applied.

Table 2. List of species and rate of seeding (lb / a) on the oil shale research plots at Piceance Basin study site June 26, 1974.

Species	Rate (lb/a)
Grasses	
Bluebunch wheatgrass (Agropyron spicatum)	1/2
Beardless wheatgrass (Agropyron inerme)	1/2
Indian ricegrass (Oryzopsis hymenoides)	1
Western wheatgrass (Agropyron smithii)	1/2
Forbs	
Lupine spp. (Lupinus spp.)	1
Utah sweetvetch (Hedysarum boreale utahensis)	3/4
Arrowleaf balsamroot (Balsamorhiza sagittata)	1/2
James penstemon (Penstemon jamesii)	3/4
Rocky Mt. penstemon (Penstemon montanus)	3/4
Shrubs	
Antelope bitterbrush (Purshia tridentata)	2
Big sagebrush (Artemisia tridentata)	1
Fourwing saltbush (Atriplex canescens)	1
Rabbitbrush (Chrysothamnus spp.)	1/2
Serviceberry (Amelanchier utahensis)	1
Mountain mahogany (Cercocarpus montanus)	1
Winterfat (Eurotia lanata)	1/2

In September 1973 and 1974 plant density by species and estimated percent ground cover were determined for each of the treatments at Anvil Points. Plant density measurements were made at the Piceance study site in September 1974. Plant density measurements were made by randomly placing four 8 x 16 inch rectangular quadrats in each plot, and counting the number of plants of each species. Percent ground cover was estimated as the total amount of ground cover (litter and plant cover).

Rainstorms caused measurable runoff on some plots at both study sites in August of 1974. Following the storm, runoff data was collected at both sites. Percent runoff, water quality, and sediment yields were determined. Analysis of the runoff samples was made by the Soil and Water Testing Laboratory at Colorado State University.

Precipitation data was recorded at Anvil Points during 1973 and 1974 with a standard U.S. Weather Bureau weighting rain gauge. A total of 3.7 inches of rainfall was received during the 1973 growing season (June-September). An additional 5.0 inches was received over the winter (October 13, 1973, through April 28, 1974). In 1974 only 1.85 inches was received during the growing season (May-September). Precipitation data was also recorded at the Piceance Basin study site; however, a 4 ft. long by 4 inch diameter steel pipe, capped at one end and then buried 12 inches in the ground, was used. A total of 4.6 inches was received between October 13, 1973, and May 10, 1974. An additional 1.5 inches was recorded during the 1974 growing season (June-September).

A weighting rain gauge with automatic event recorder will be installed at each study site in 1975.

RESULTS AND DISCUSSION

Salinity Measurements (Anvil Points, 1973-74)

Soluble salts were reduced to low levels by leaching the Anvil

Points spent shale plots with 40 inches of water in May 1973. However, the TOSCO spent shale was later resalinized by salts dissolved in water carried upward by capillary rise.

Soluble salts in soils are measured by the electrical conductivity (EC) of a solution extracted from the soil. In soil analyses the EC determinations are usually made on saturation extracts as was the procedure in this study; an EC value of 4 mmhos and greater indicates a saline soil, whereas, EC values of 16 mmhos and greater indicate extremely saline soil in which many species will not grow.

The EC of unleached TOSCO spent shale is about 15 mmhos. After leaching, the Anvil Points spent shale plots were sampled and found to have EC values of less than 2 mmhos to a depth of 4 feet. The plots were again core sampled on October 13, 1973. At this time the EC had risen to about 5 mmhos in the top 4 feet (Fig. 4a,b). By the following spring (1974) it appears that some leaching of salts had occurred during the winter from the 5 inches of precipitation received between October and April. However, there was no indication of leaching of the TOSCO spent shale south aspect (Fig. 4b) during this period. The September 1974 sampling indicated resalinization of the TOSCO profiles to EC values greater than 10 mmhos (Fig. 4a,b). The sampling results from the USBM spent shale plots (Fig. 4c,d) indicated no significant resalinization during the 1974 growing season.

The 6 inches of soil cover over leached TOSCO spent shale on both the north and south aspects was salinized by salts dissolved in water carried upward by capillary rise (wick action) from the underlying spent shale. EC values of greater than 10 mmhos were measured in the surface 2 inches on September 6, 1974 (Fig. 5a,b). In contrast, the

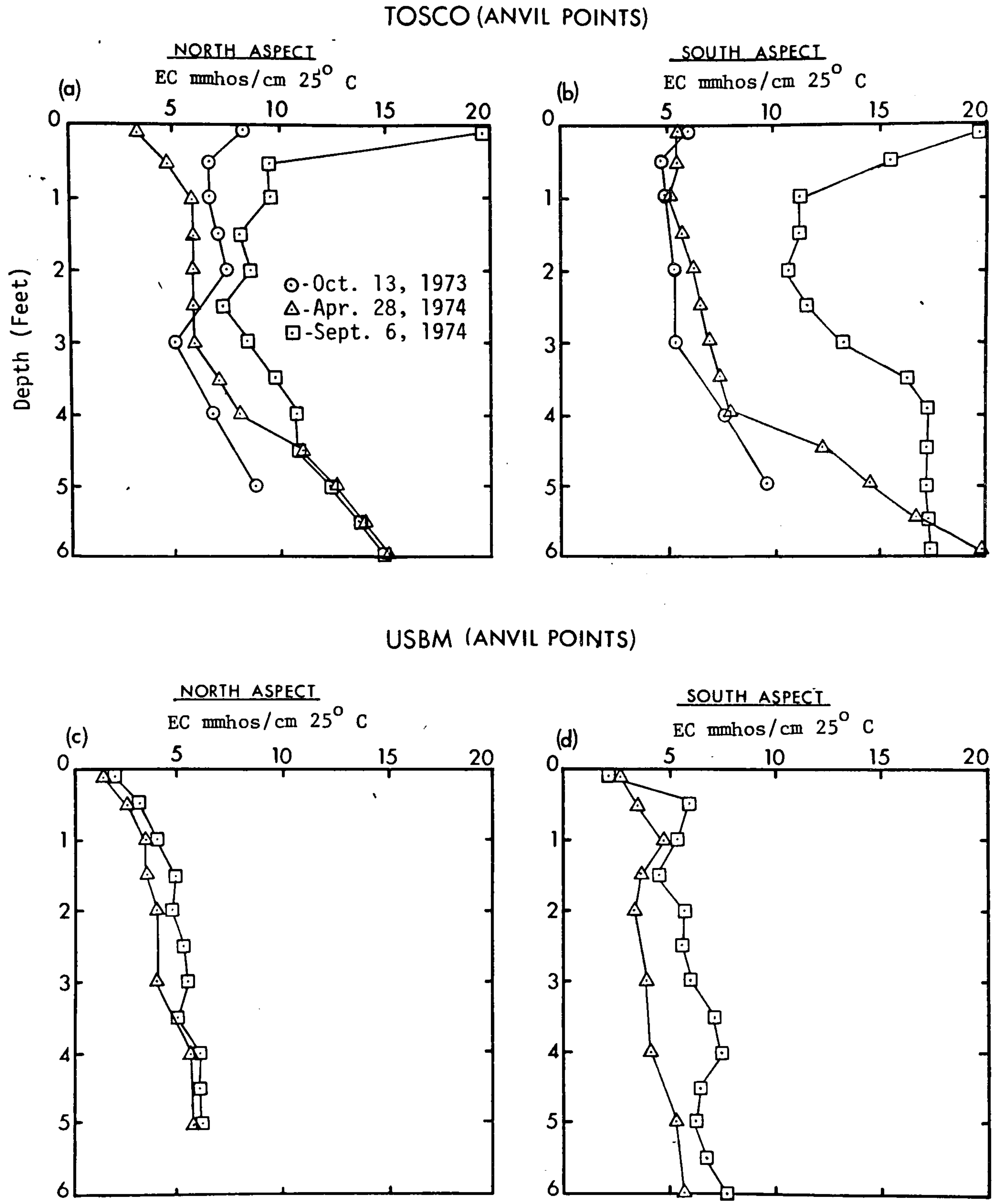


Figure 4 (a, b, c, d). Salinity profiles in TOSCO and USBM spent treatments showing the effect of winter leaching and capillary rise during the summer (Anvil Points, 1973-74).

TOSCO (ANVIL POINTS)

6" SOIL COVER OVER LEACHED TOSCO

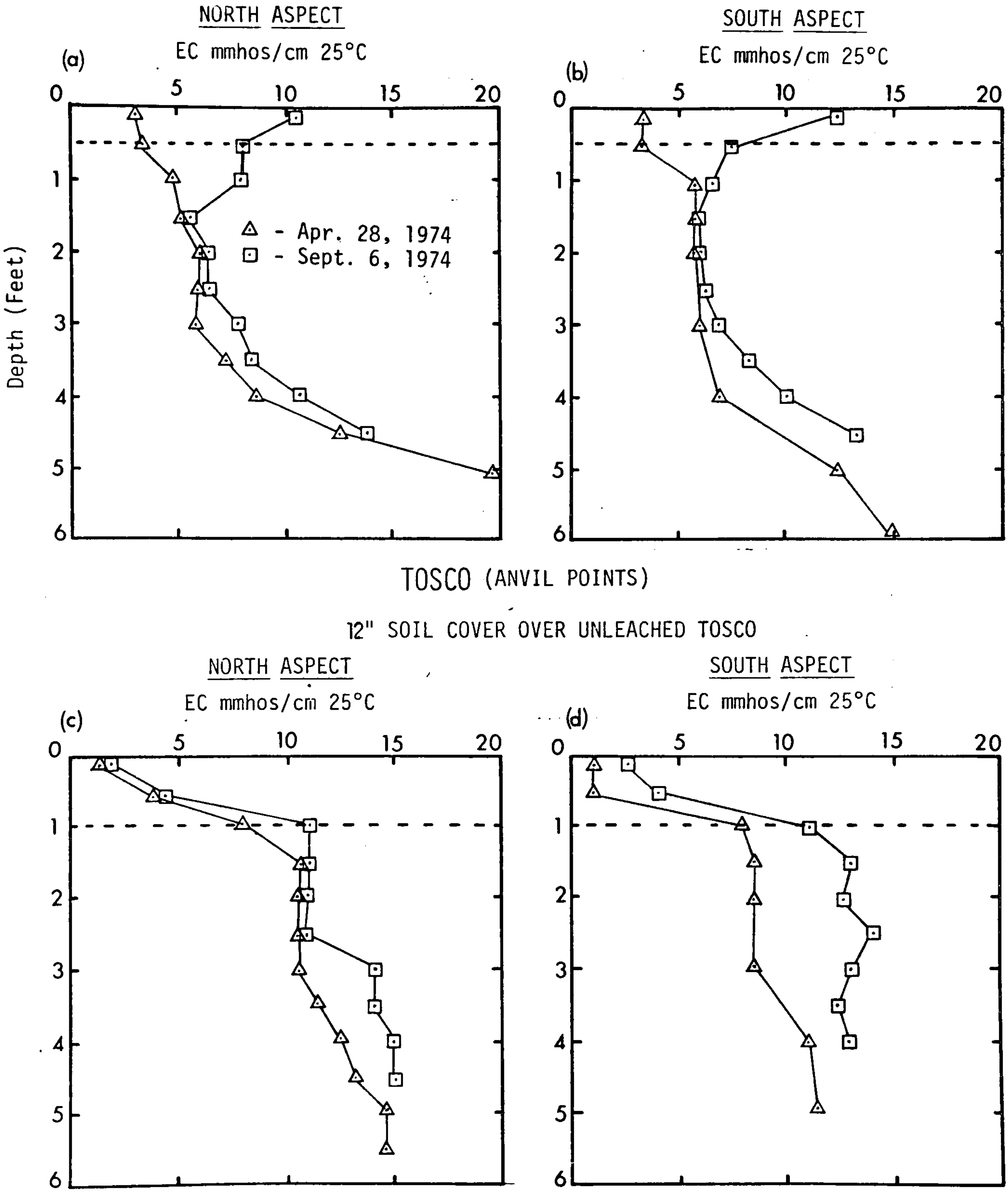


Figure 5 (a, b, c, d). Salinity profiles in treatments of 6" and 12" soil cover over TOSCO spent shales. 12" soil cover treatments were unleached. Salinization of the 6" soil cover is shown (Anvil Points study site, 1974).

12 inches of soil cover over unleached TOSCO spent shale was not salinized; however, there appears to be some salt movement upward from the spent shale into the soil (Fig. 5c,d). Little if any movement of salts into the 6 and 24 inch soil cover over USBM spent shale occurred (Fig. 6).

The salinization of the TOSCO spent shale treatments can be attributed to the following factors:

1. The uniform silty texture develops small capillary pores. The capillary pores in turn conduct water and dissolved salts upward in response to a potential developed by evaporation at the spent shale surface.
2. The silty material also has a high moisture-holding capacity which provides sufficient water for evaporation and the resulting upward salt movement after leaching.

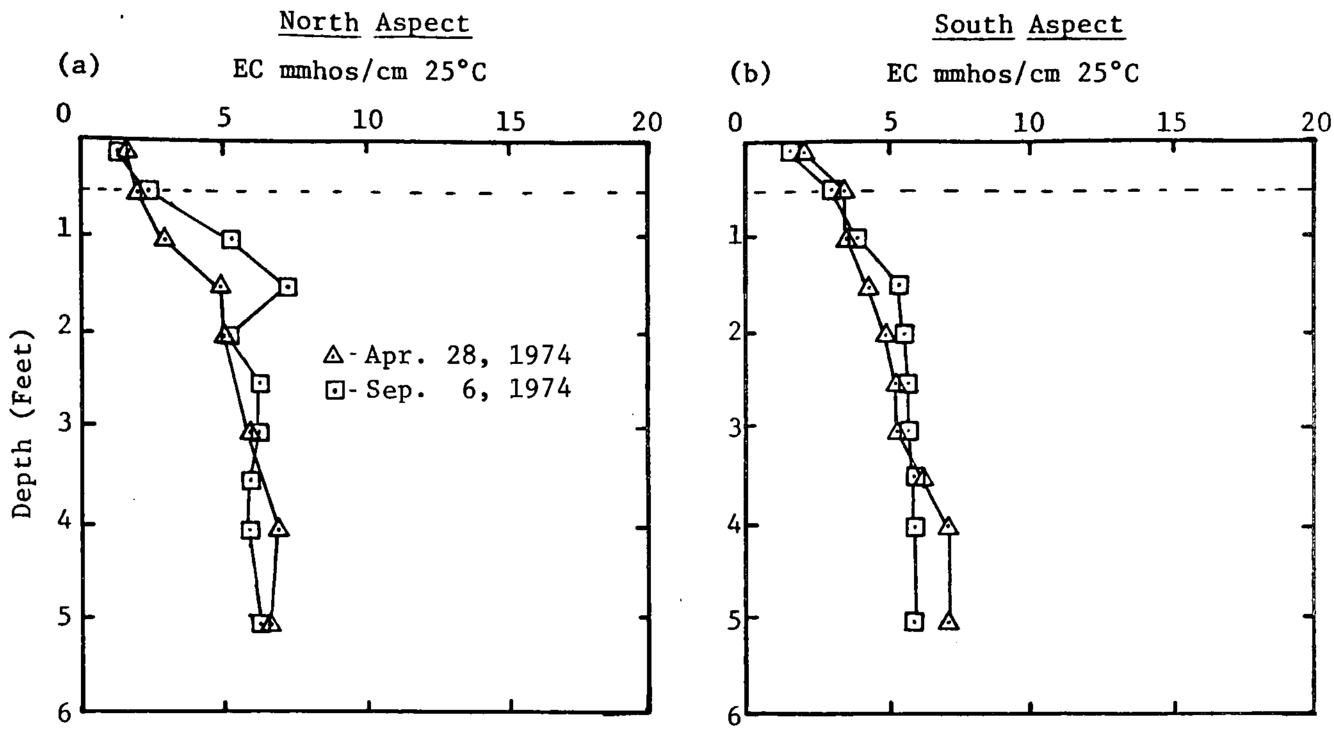
The salinization of 6-inch soil cover over leached TOSCO spent shale can also be attributed to capillary rise, both in the underlaying spent shale and in the soil cover. Apparently there is not adequate textural differences between the loam soil cover and the silt loam TOSCO spent shale to prevent the development of capillary pores across the spent shale-soil interface.

The lack of salinization of the 12 inches of soil cover over unleached TOSCO spent shale can be attributed to the lower moisture content of the unleached spent shale.

The USBM spent shale and soil cover over USBM spent shale treatments on the Anvil Points plots were not salinized in either 1973 or 1974. The lack of salinization can be attributed to the coarser texture of the USBM spent shale.

USBM (ANVIL POINTS)

6" SOIL COVER OVER LEACHED USBM



USBM (ANVIL POINTS)

24" SOIL COVER OVER UNLEACHED USBM

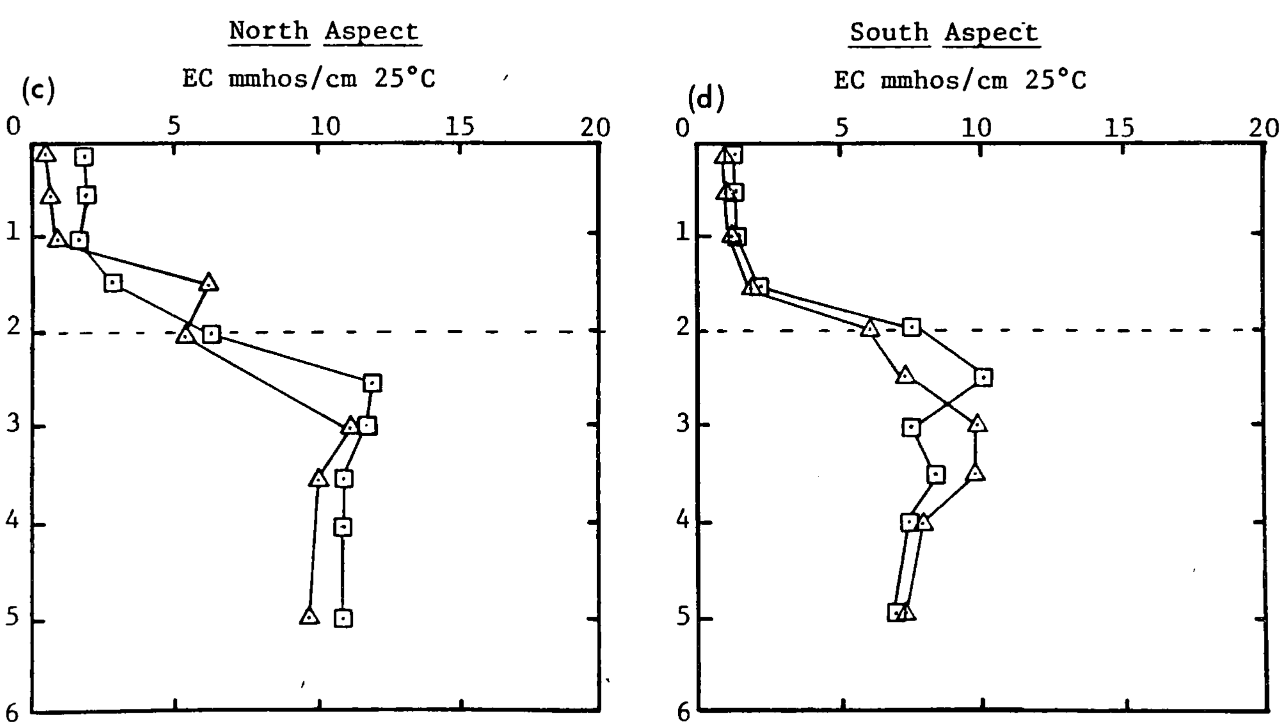


Figure 6 (a, b, c, d). Salinity profiles in treatments of 6" and 24" of soil cover over USBM spent shale, 24" soil cover was not leached (Anvil Points study site, 1974).

Salinity Measurements (Piceance Basin 1973)

The Piceance Basin study site was initially leached with 20 inches of water during a four-week period in August and September 1973. Analysis of core samples obtained from the TOSCO spent shale in October 1973 indicated high levels of soluble salts remained in the spent shale (Fig. 7a,b).

The TOSCO spent shale plots were core sampled again on May 23, 1974, and the results show a decrease in EC throughout profiles on both the north and south aspects. The decrease in salinity between October 1973 and May 1974 was a result of leaching from winter snow melt. There was more effective winter-leaching on the south aspect than on the north aspect (Fig. 7a,b). The increase in EC values in the upper 12 inches of the TOSCO south aspect (Fig. 7b) on May 23 indicates that movement of water and dissolved salts to the surface by capillary rise had already occurred; however, on the north aspect (Fig. 7a), capillary rise had not occurred by the May sampling date. The photograph in Figure 3 shows the salt crust on the south aspect of TOSCO spent shale treatments on May 23, 1974. The corresponding north aspect TOSCO spent shale did not have a salt crust on May 23.

The difference between the more effective leaching and yet the development of a salt crust by May 23 on the TOSCO south aspect was apparently the result of heavy snow accumulation on the south aspect during the winter and rapid melting in early spring. Snow drifts with an average depth of 30 inches were measured on November 23, 1973, across the south aspect of the TOSCO spent shale pile. While the corresponding north aspect only had 6 to 8 inches of snow cover.

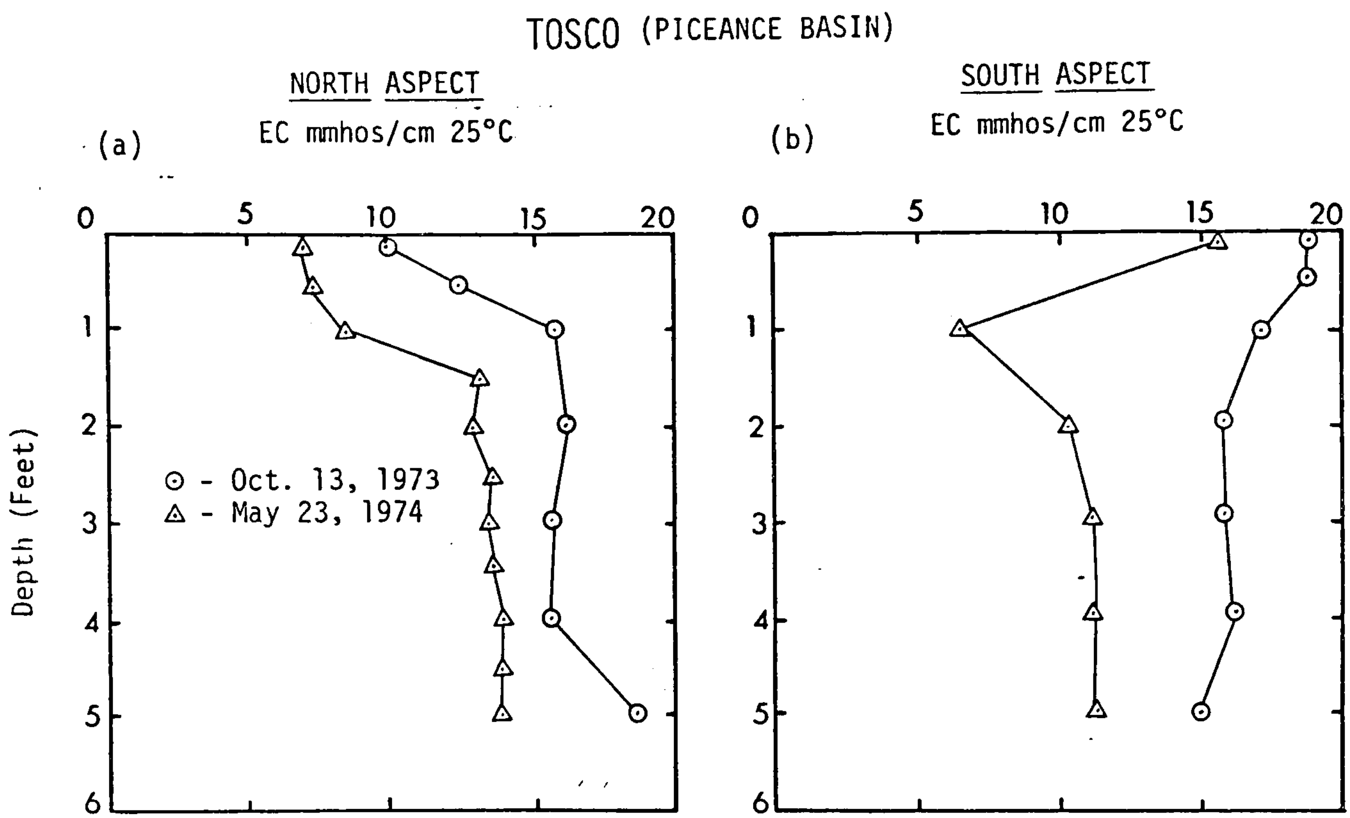


Figure 7 (a, b). Salinity profiles in TOSCO spent shale treatments, showing the leaching by snow melt (Piceance Basin study site, 1973-74).

Salinity Measurements (Piceance Basin 1974)

The Piceance plots were leached with an additional 40 inches of water in June 1974. Following leaching, the plots were core sampled on June 26, and the results show more effective leaching on the north aspect (Fig. 8a) than on the corresponding south aspect (Fig. 8b) for TOSCO spent shale. The USBM spent shale on both north and south aspects (Fig. 8c,d) were more effectively leached than the TOSCO spent shale treatments.

Both spent shale plots were core sampled again on September 10, 1974, and the results show that the TOSCO and USBM spent shales were resalinized and had EC values of 15 mmhos and greater at the surface (Fig. 8a,b,c,d). In addition, the results of the September sampling indicated that the 6 inches of soil cover over both TOSCO and USBM spent shales was becoming salinized (Table 3). There is no indication of the 12-inch soil cover on the USBM spent shale becoming salinized. There is an indication of some salt movement up into the 12-inch soil cover on the TOSCO spent shale (Table 3).

Table 3. Salinity measurements for soil control and soil cover over spent shales. Values are EC mmhos/cm 25° C, saturated paste. (Piceance Basin study site, September 10, 1974).

	SOIL		TOSCO				USBM			
			6"*		12"		6"		12"	
Depth	North	South	North	South	North	South	North	South	North	South
Surface	.9	.9	3.0	4.5	1.3	1.0	1.2	2.5	.5	.7
6"	.6	1.0	1.4	3.1	.9	1.0	.6	1.4	.4	.5
12"	.7	.8	-	-	3.0	3.5	-	-	1.0	.5

* Depth of soil cover over spent shale.

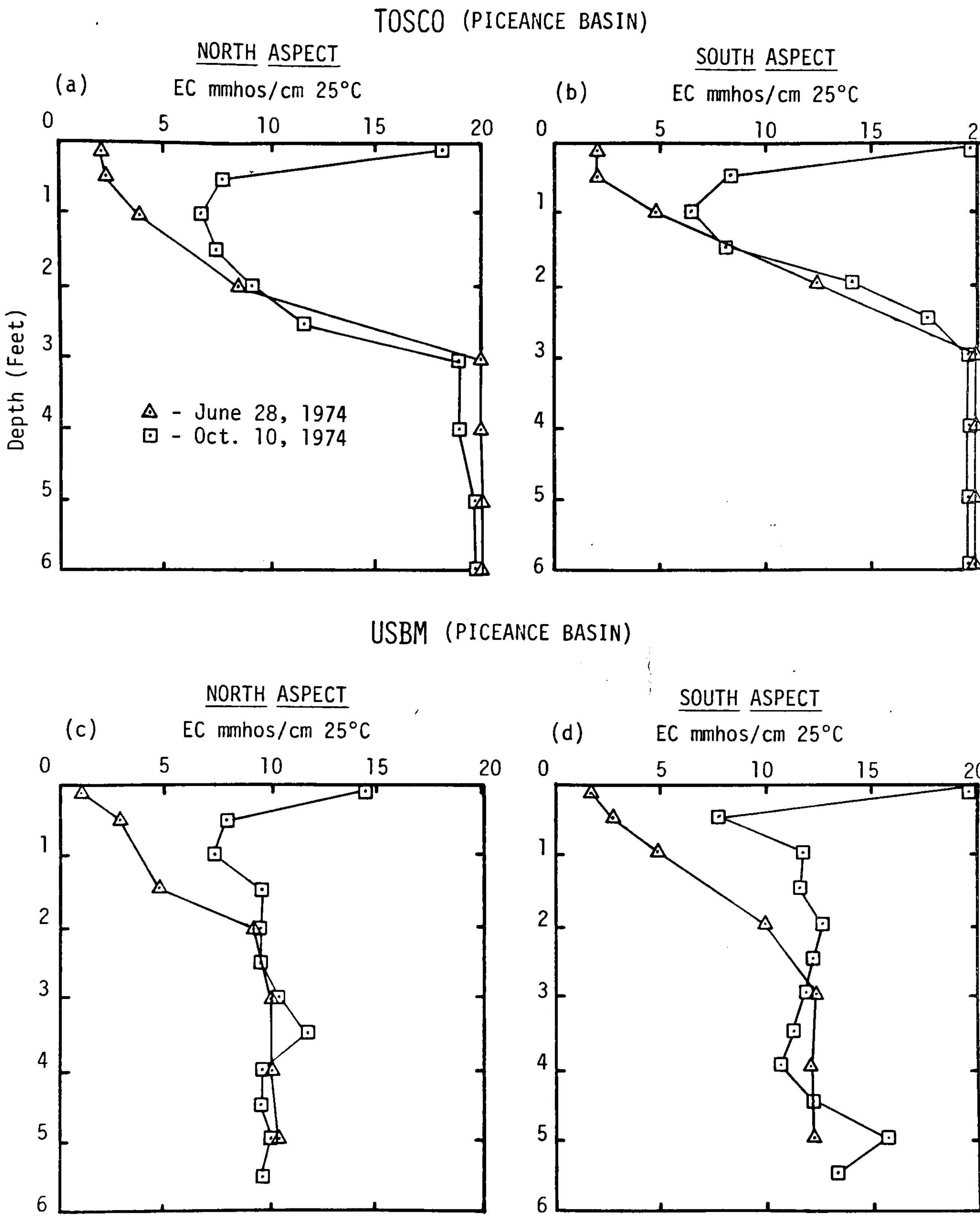


Figure 8 (a, b, c, d). Salinity profiles in TOSCO and USBM spent shale treatments showing resalinization of the leached spent shales (Piceance Basin study site, 1974).

The more effective leaching on the spent shales at Anvil Points then at the Piceance Basin site can be attributed to the following:

1. The use of moderately saline water (EC .7 to 1.0 mmhos) at the Piceance Basin site and high quality water at Anvil Points.
2. The USBM and the TOSCO spent shales at Piceance Basin site were compacted to higher bulk densities during construction to minimize settling--this results in creation of smaller pores and a greater capillary rise potential.
3. The sprinkler irrigation system design used at both sites was identical. However, the leach water was applied continuously for two 5-day periods at Anvil Points but was only applied intermittently (1.0 inch/day with approximately 6 hours required to apply) at the Piceance Basin site.
4. The sprinkler irrigation efficiency was reduced at the Piceance Basin site by the prevailing south-southwest wind (10-15 mph) during leaching. In addition, relative humidities were low and daily maximum temperatures were between 85 and 95^{o} F.

<u>Moisture Measurements (Anvil Points 1973-74)</u>

Upon completion of leaching and seedling establishment in late July of 1973, the spent shales were at field capacity (approximately 35% by volume). However, by October 13, 1973, the moisture content in the spent shale was depleted to 28 percent by volume.[1]

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[1] The percent moisture values given in Figure 9 were obtained from a calibration curve developed for soils and, therefore, the values do not report the actual moisture content for the spent shales; however, the relative differences as plotted in Figure 9 are valid. Calibration curves are presently being developed for both the TOSCO and USBM spent shales.

Moisture readings were made every 15 days between April 18 and July 1, 1974, at Anvil Points; by June 15 available plant moisture was depleted to a depth of 30 inches in all treatments. The September 1974 soil moisture readings show the available plant moisture was depleted throughout the entire profile in each spent shale (Fig. 9). In general the results in Figure 9 are representative of the results obtained from all the plots at Anvil Points. There was no significant difference in plant available moisture depletion patterns between the spent shale plots and the soil control plots.

Moisture Measurements (Piceance Basin 1974)

Plant available moisture was depleted in both spent shales to a depth of 18 inches and was depleted to a depth of 30 inches in the soil control plots by September 1974 on the Piceance Basin site. The difference in moisture depletion between the spent shales and soil control was due to excellent plant growth on the soil control plots and only moderate plant growth in the spent shales.

Surface Temperature Measurements (Anvil Points 1973-74)

Extremely hot surface temperatures (150° F) were recorded in the summer of 1974 on the TOSCO spent shale surface. In contrast, maximum surface temperatures of 118° F were recorded on the soil. The mean maximum monthly temperatures for 1973 and 1974 are shown in Table 4. The surface temperatures for 1973 were cooler than the surface temperatures in 1974 because the plots were leached, mulched and irrigation water was applied almost daily in June and July 1973.

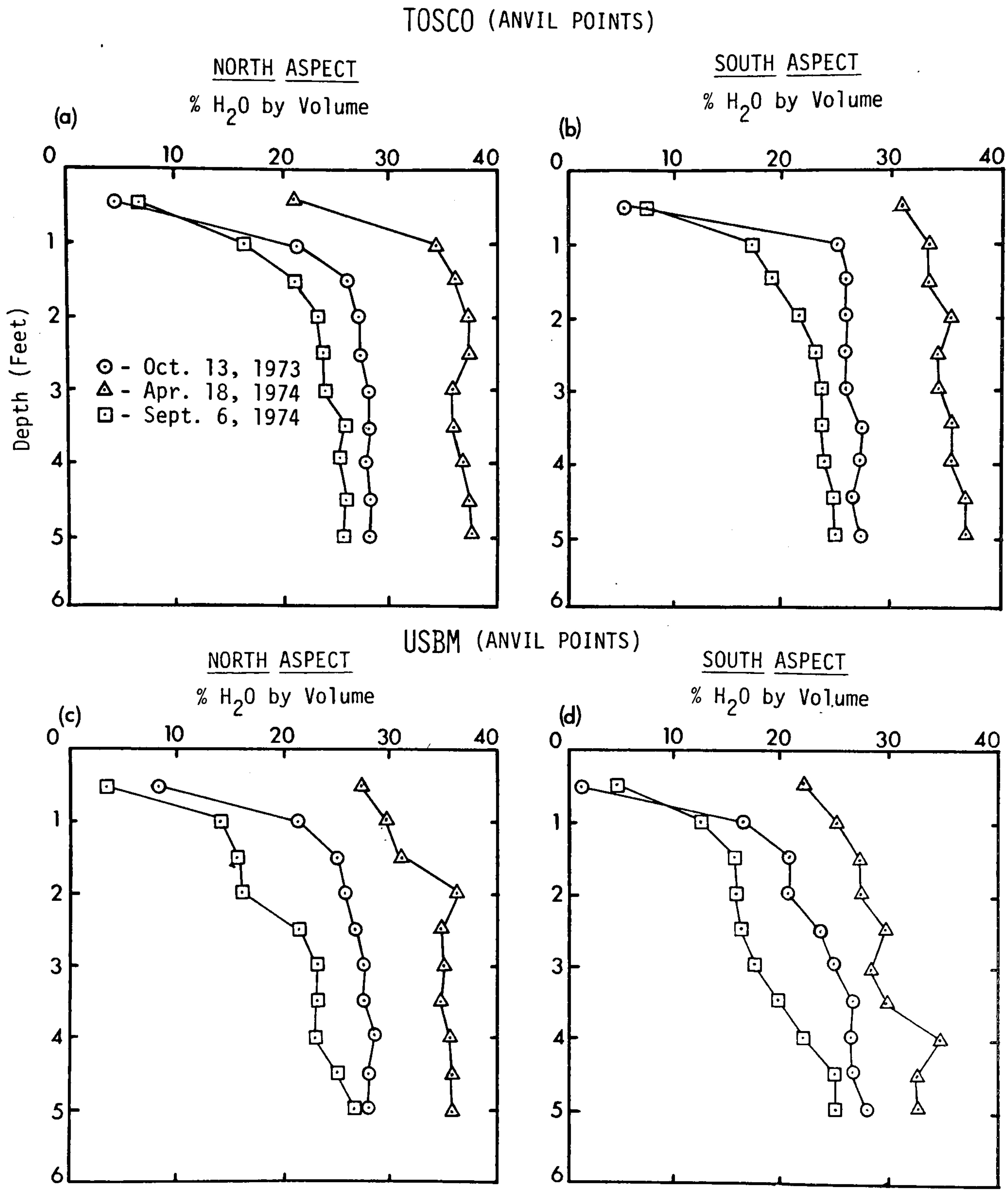

Figure 9 (a, b, c, d). Moisture profiles in TOSCO and USBM spent shale treatments showing profile recharge over the winter and use during the growing season (Anvil Points study site, 1973-74).

Table 4. Mean maximum monthly surface temperatures (^oF) for TOSCO spent shale and 6" soil cover over TOSCO spent shale, north and south aspect. Anvil Points study site, 1973 and 1974.

Treatment	Aspect	April 73	April 74	May 73	May 74	June 73	June 74	July 73	July 74	Aug. 73	Aug. 74	Sep. 73	Sep. 74
TOSCO	North	-	50	-	71	79	88	83	88	79	80	74	64
TOSCO	South	-	48	-	80	74	104	81	131	88	108	86	113
Soil	North	-	50	-	70	80	88	86	104	80	86	75	75
Soil	South	-	60	-	72	86	104	93	118	88	100	84	104

In April 1974 the TOSCO south aspect plot was 12^o (F) cooler than the corresponding soil cover south aspect, however there was no difference in the surface temperatures between these treatments on the north aspect. In May 1974 the TOSCO south aspect temperatures averaged 8^o (F) cooler than the soil cover temperatures. By July the maximum temperatures on the TOSCO south aspect was averaging 131^o (F) per day with 150^o (F) maximum temperatures recorded during June, July and August. The cooler spent shale surface in May was caused by surface evaporation of stored water from the spent shale profile. Once the moisture available for evaporation was depleted the temperature increased rapidly.

A typical summer diurnal temperature curve for surface temperatures on the TOSCO spent shale and soil cover is shown in Figure 10.

Vegetation Measurements (Anvil Points 1973-74)

A good vegetative cover of native species was established at Anvil Points by late July 1973 (Fig. 11a). Major shifts in the relative density of the established species occurred between September

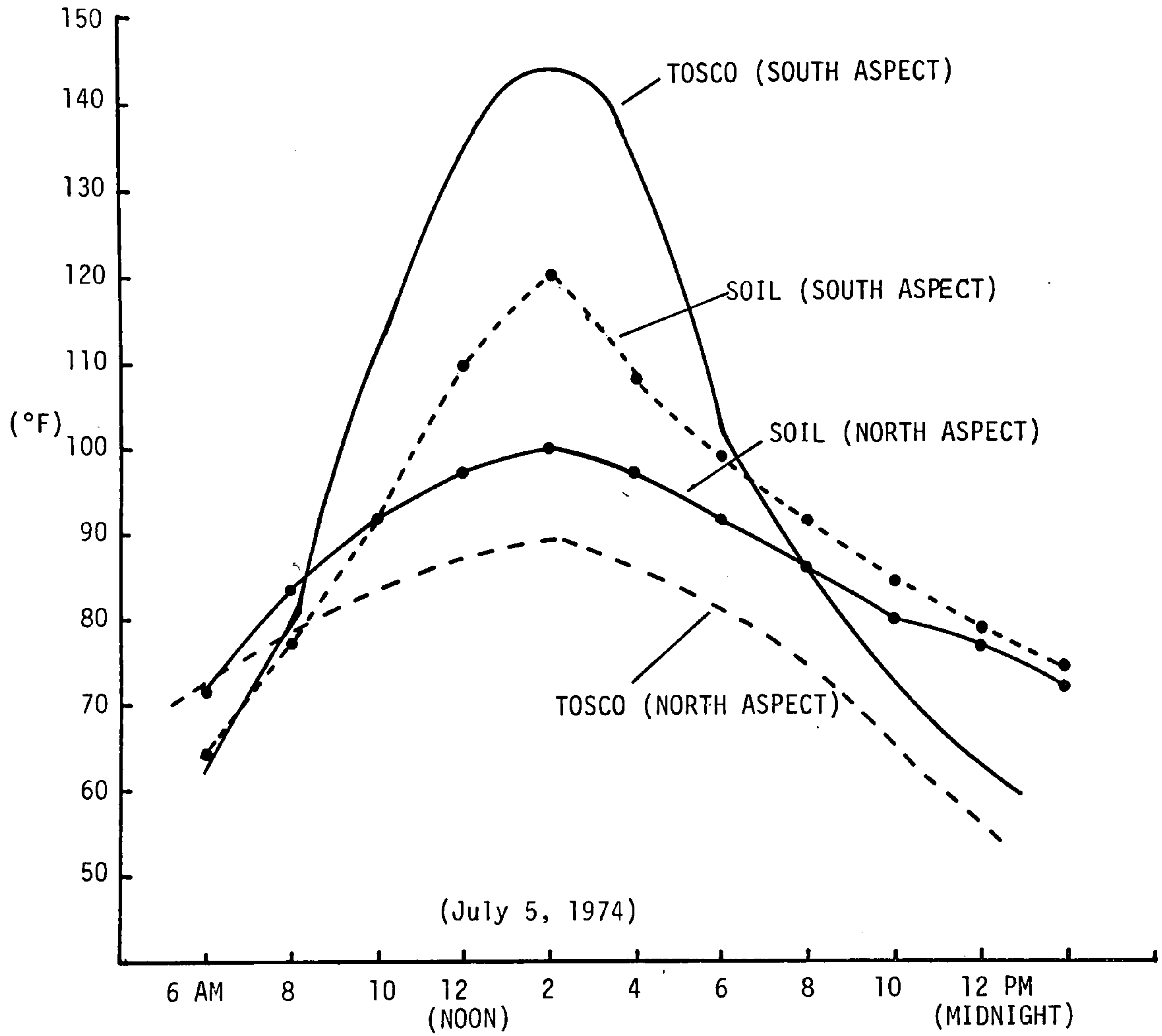

Figure 10. Surface temperatures of TOSCO spent shale and 6" of soil cover over TOSCO spent shale, north and south aspects (Anvil Points study site, July 5, 1974).

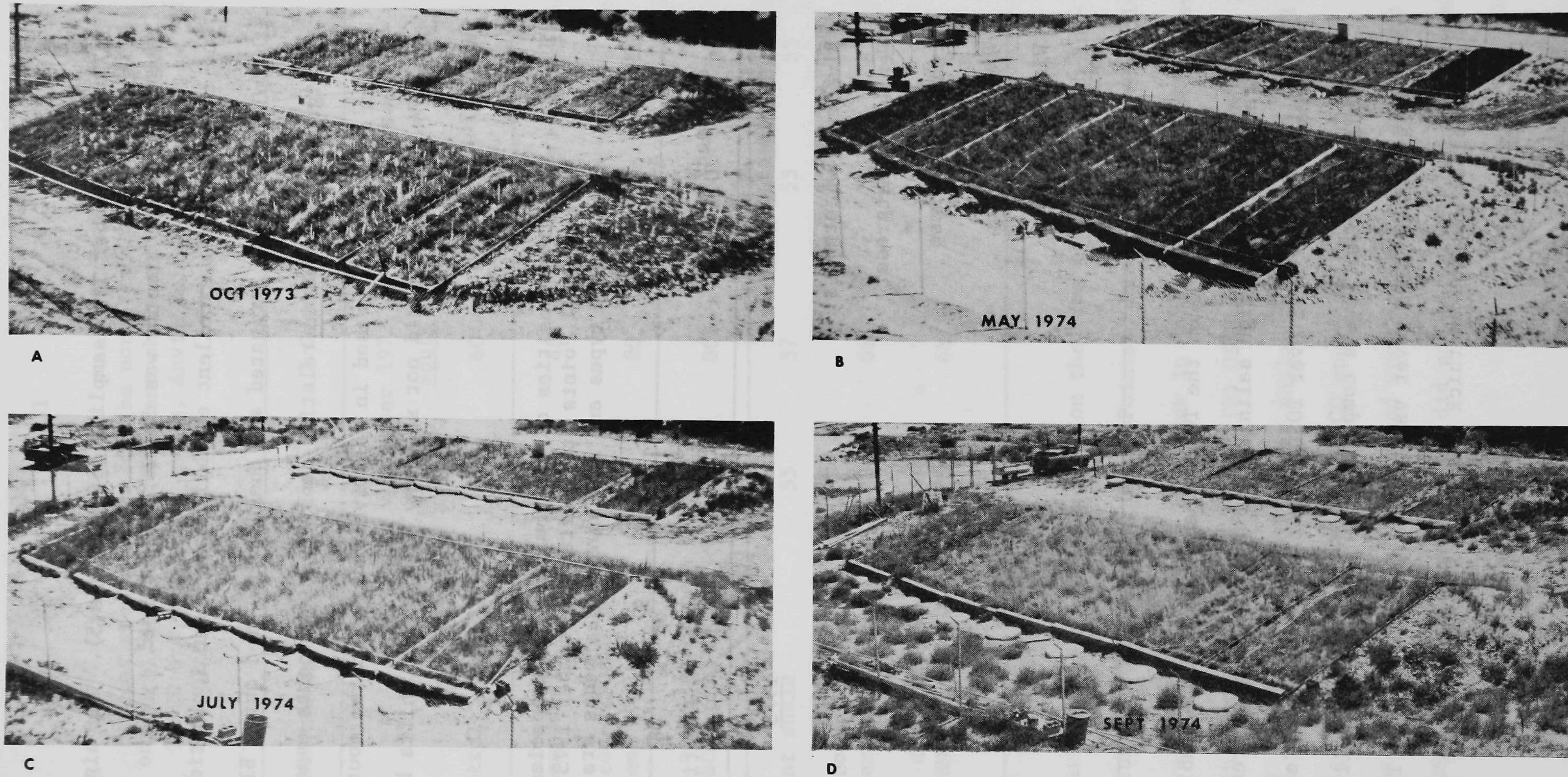

Figure 11 (a, b, c, d). Vegetative cover for the north aspect of the USBM and TOSCO research plots (Anvil Points study site - 1973-74).

1973 and September 1974 sampling dates (Table 5). The high 1973 relative density for timothy was due to timothy seed in the hay mulch and the subsequent excellent establishment under irrigation. In 1974 the plots were not irrigated and the timothy died out. Bluebunch wheatgrass increased in relative density on the north aspects and Indian ricegrass increased in relative density on the south aspects in 1974. The shrubs did not show any significant shifts between 1973 and 1974.

Table 5. Relative densities of the dominant plant species growing on the Anvil Points study site - September 1973 and 1974. Spent shale types and soil cover treatments are not differentiated.

Species	% Relative Density	
	1973	1974
Bluebunch wheatgrass	28.3	43.3
Western wheatgrass	26.9	27.2
Indian ricegrass	8.0	22.7
Timothy	33.1	1.8
Winterfat	3.0	3.4
Fourwing saltbush	0.7	1.6

Cover decreased on the TOSCO spent shale plots (Table 6) apparently in response to the high salinity and surface temperatures. Cover also decreased on the soil over TOSCO spent shale; this decrease, however, was only to cover levels comparable to those on the soil control. The original (1973) high cover values for the soil-covered TOSCO spent shale plots was due to thick stands of timothy on these plots but not on other plots.

Table 6. Percent ground cover for the north and south aspects soil control, TOSCO and USBM spent shale and soil cover over TOSCO and USBM spent shale, Anvil Points study site, 1973 and 1974.

Treatments	% Ground Cover			
	September 1973		September 1974	
	North	South	North	South
Soil Control	65	60	65	60
TOSCO spent shale	53	48	43	43
6" soil cover/TOSCO spent shale	80	80	63	58
12" soil cover/unleached TOSCO spent shale	80	80	63	60
USBM spent shale	55	57	55	55
6" soil cover/USBM spent shale	73	68	75	62
24" soil cover/unleached USBM spent shale	73	68	68	60

Observations were made in 1974 on the time of plant growth initiation for each treatment at Anvil Points. Growth began on the following treatments during the last week in April 1974: (1) TOSCO spent shale with 12 inches of soil cover, (2) USBM spent shale with 6 and 24 inches of soil cover, (3) USBM spent shale, and (4) the soil control plots (Fig. 11b). Growth on the TOSCO spent shale with 6 inches of soil cover was initiated by the second week in May; but plant growth on the TOSCO spent shale treatments did not begin until the last week in May. Figure 11b was photographed May 10, 1974. The dark color (green) of some plots represents new growth. The delay in growth initiation on the TOSCO spent shale treatment was apparently due to cooler surface temperatures caused by the evaporation of stored moisture. Once the moisture available for evaporation was depleted, the surface warmed rapidly and new growth started. (See the results section on surface temperatures at Anvil Points.)

On July 3, 1974, (Fig. 11c) only the TOSCO spent shale, TOSCO spent shale with 6 inches of soil cover, and the soil control plots contained actively growing plants. On the other treatments the plants had matured and set seed. The soil control plots in Figure 11d are darker in color, which represents new plant growth following 1 inch of precipitation received in August 1974.

The 1974 reduction in plant growth on the TOSCO spent shale can be attributed to the following factors:

1. Low surface temperatures in April and May caused by evaporation of water brought to the surface by capillary rise.
2. High salt content in the surface as a result of the movement of dissolved salt upward with the capillary water.
3. High surface temperatures (150° F) recorded during late June, July and August on the spent shales.

Even greater differences in plant cover among the spent shale and soil cover treatments are expected in the future.

Vegetation Measurements (Piceance Basin 1974)

Stand establishment was poor for grasses and fair to good for shrubs and forbs on the Piceance Basin plots. One reason for the thin grass stands is that very low seeding rates (Table 2) were used in an attempt to obtain stands similar in density to stands supported by the natural precipitation. Another reason is competition from barley growing from viable seeds in the mulch despite methyl bromide treatment. The barley was hand pulled in late August and data was collected on the remaining seeded species. The results of quadrat analysis show fair to poor establishment of the grasses. Establishment of big sagebrush was excellent; as many as 20 plants were counted per quadrat (8 in. x 16 in.). Mountain mahogany and bitterbrush also had good establishment; however, the other shrubs listed in Table 2 only showed fair to no establishment. Utah sweet vetch and the penstemons also had good establishment. No arrowleaf balsamroot was found.

Due to the poor to fair establishment of the grass species seeded in June 1974, the Piceance Basin plots were reseeded on October 18, 1974. At this time the plots were furrowed lightly (so as not to destroy the established plants) and seeded with western wheatgrass (7 lb/a), bluebunch wheatgrass (7 lb/a) and Indian ricegrass (7 lb/a), raked lightly and mulched. In addition, big sagebrush seedlings were hand thinned to prevent the plots from becoming dominated by this species.

To insure development of adequate vegetative cover in the spring of 1975, an additional 20 inches of leach water will be required in May and supplemental irrigation through June. The additional seeding, leaching and supplemental irrigation is required to insure adequate vegetative (approximately 60-70%) cover, similar to that obtained at Anvil Points in 1973. Once the plant cover is established, no additional irrigation water will be applied.

Analysis of Barley Plants Collected from the Piceance Basin Site 1974

Molybdenum and zinc were higher in barley grown in the spent shales than in soil (Table 8). These plant samples were collected on August 15, 1974, from the Piceance Basin plots. No discussion of the ramifications of the results given in Table 8 are made as we feel that more detailed research is needed.

Runoff Measurements (Anvil Points 1974)

The Anvil Points study site received .75 inches of rain in 30 minutes from a thunderstorm on August 14, 1974. On August 15 the total runoff was measured from each plot and samples taken for water quality analyses. In general the runoff was extremely low for all plots (Table 9). The only plots with significant runoff in comparison to the soil control plots were the TOSCO spent shale treatments. The low sediment yields are a reflection of the rather dense ground cover of living and dead vegetation and mulching residue. Runoff water from all treatments was somewhat saline. Comparison of runoff water quality between the soil and spent shale treatments must take into consideration the difference in total runoff; if this is done the quantity of soluble salts in runoff from the TOSCO spent shale was much greater than from the soil.

Runoff Measurements (Piceance Basin 1974)

A total of .50 inches of rainfall fell on the Piceance Basin study site on August 14, 1974. No information was obtained on storm duration, intensity, or wind direction. Total runoff was measured and samples were collected for water quality analyses.

The results show a significant amount of runoff from the TOSCO spent shale treatments in comparison to the soil control plots (Table 10).

Table 8. Elements found in the analysis[1/] of mature barley plants growing on spent shale and soil plots. (Piceance Basin study sites, August 15, 1974). The values given are in ppm dry weight basis, and are means of two replications per treatment.

Treatments	K	Ca	Mn	Fe	Cu	Zn	Sr	Zr	Mo	Cd
TOSCO										
North	37676	5700	56.0	82.7	15.4	58.7	23.5	0	8.6	.83
South	29490	4133	49.5	95.6	13.8	67.0	24.4	0	11.9	.86
USBM										
North	44453	6397	24.5	122.2	18.6	24.0	41.8	.70	12.9	.56
South	52831	10752	22.6	148.0	21.5	34.7	50.5	1.3	18.0	.43
SOIL										
North	32749	3532	49.6	91.0	16.5	17.5	42.2	.33	3.0	1.6
South	28343	10279	60.0	200.0	18.6	23.4	51.6	.89	2.8	.95

1/ Analyses were made in cooperation with Dr. G. M. Ward, Animal Science Department, CSU. The analyses were made by the University of Colorado in conjunction with the Transport and the Biological Effect of Molybdenum in the Environment Project.

Table 9. Runoff, sediment yield, and water quality from a .75 inch, 30-minute storm at Anvil Points study site, Aubust 14, 1974.

	TOSCO						USBM						SOIL	
	Spent Shale		6" Soil Cover		12" Soil Cover		Spent Shale		6" Soil Cover		24" Soil Cover			
	North	South	North	South	North	South	North	South	North	South	North	South	North	South
Runoff, gallons	9.4	2.3	T*	.8	T	T	.4	.4	T	T	.4	T	T	.5
Runoff, %	.82	.20		.07			.03	.03			.03			.04
Sediment lb/a	200	145		25			12	52			8			12
EC mmhos/cm 25°C	1.5	1.5		1.3			1.9	1.4			1.2			1.1
pH	7.0	7.1		7.0			7.6	7.3			7.2			7.7
Cations														
Ca ppm	147	146		100			122	123			100			75
Mg ppm	74	33		21			36	26			20			16
Na ppm	67	29		34			161	62			79			70
K ppm	22	35		70			70	64			98			69
Anions														
HCO_3 ppm	113	179		500			543	418			584			451
Cl ppm	17	36		35			198	66			34			40
SO_4 ppm	822	104		144			192	168			408			115
NO_3 ppm	3	3		5			6	6			3			4

* T denotes trace of runoff, less than .2 gallon.

Table 10. Runoff, sediment yield, and water quality from a .50 inch storm at the Piceance Basin study site, August 14, 1974

	TOSCO						USBM						SOIL	
	Spent Shale		6" Soil Cover		12" Soil Cover		Spent Shale		6" Soil Cover		24" Soil Cover			
	North	South	North	South	North	South	North	South	North	South	North	South	North	South
Runoff, gallons	2.8	7.4	.4	T*	T	T	.4	.7	.5	.5	T	T	T	.4
Runoff, %	.37	.97	.05				.05	.09	.06	.06				.05
Sediment lb/a	27	162	12				.7	8	2	5				8
EC mmhos/cm 25°C	3.0	2.2	.85				1.2	1.9	1.2	.92				.73
pH	7.1	7.5	7.4				8.0	7.5	7.9	7.6				7.6
Cations														
Ca ppm	350	301	69				89	165	57	73				67
Mg ppm	174	103	17				32	74	25	17				17
Na ppm	131	66	52				56	137	74	59				22
K ppm	12	10	9				7	22	28	6				3
Anions														
HCO_3 ppm	88	100	195				251	198	364	207				238
Cl ppm	15	10	40				35	27	40	25				12
SO_4 ppm	1584	1236	175				276	744	233	238				77
NO_3 ppm	.3	.4	.8				.8	4.4	.3	.3				1

* T denotes trace of runoff less than .2 gallon.

However, the total runoff from any one treatment was very low when compared to total rainfall received. The water quality results (Table 10) tend to show lower quality runoff water from the spent shales than from the soil control.

SUMMARY

Plots of spent oil shales (TOSCO and USBM) and soil-covered spent shales were established in 1973 at the U.S. Bureau of Mines (Anvil Points Oil Shale Research Facility, 5,700 feet) near Rifle, and in the Piceance Basin (7,200 feet). The Anvil Points plots were leached with 40 inches of water in May 1973, seeded on June 11 with a mixture of native grasses and shrubs, mulched, and fertilized. An additional 18.5 inches of water was then applied for establishment. Seedling establishment was good. The Piceance Basin plots were leached with 20 inches of water in August 1973 and 40 inches of water in June 1974. The plots were seeded with a mixture of native species on June 26, mulched and fertilized. An additional 11.0 inches of water was applied for establishment. However, seedling stands were thin, and the plots were reseeded on October 18, 1974.

Salinity data collected at both sites show resalinization following leaching of the TOSCO spent shale and salt movement up into 6 inches of soil cover over leached TOSCO spent shale. The USBM spent shale was resalinized at the Piceance site in 1974 but was not resalinized at Anvil Points in either 1973 or 1974. The 12 inches of soil cover over unleached TOSCO or unleached USBM spent shales was not salinized at either study site. Maximum surface temperatures of 150^{o} F were recorded on the south-facing TOSCO spent shale plot in late

June, July and August 1974 at Anvil Points. Maximum surface temperature of 113° F was recorded on the south-facing soil cover at the same time.

High levels of molybdenum and zinc were found in barley plants growing directly in both the TOSCO and USBM spent shale when compared to plants growing in the soil; the plants were collected from the Piceance Basin study site on August 1974.

Measureable amounts of runoff were collected from both the spent shale and soil treatments at each site in August 1974. The greatest runoff at both sites was from the fine-textured TOSCO spent shale. Water quality analyses show that moderately saline runoff water was collected from both spent shale and soil plots at each site.

Future of This Study

We hope to maintain and monitor this study for a number of years. It is expected that vegetation will become less dense and runoff will increase as the stands established by irrigation thin to stands that can be supported under the prevailing climatic and soil conditions.

Funds have been obtained from the EPA to finance the study through July of 1975 and a continuation will be requested. A more detailed report on this study will be available later this year in the thesis of the senior author.

Acknowledgements

Our thanks to the following agencies and individuals who helped and cooperated on this study:

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The Colorado Department of Natural Resources who secured the initial funding from state, federal and private sources.

The EPA, National Environmental Research Center in Cincinnati for funds to instrument and continue observations on the study.

The U.S. Bureau of Mines who provided the Anvil Points study site and irrigation water in addition to the USBM spent shale.

The Colony Development Operation for providing and loading the TOSCO spent shale.

The Bureau of Land Management for the Piceance Basin study site and use of their water storage tank.

The Department of the Navy for providing funds for fencing the Anvil Points site.

The Soil Conservation Service for seeds of certain hard-to-obtain native species.

And, above all to those who worked hard and carefully to build and establish the plots--Bob Squires and Curley George of Rifle and Enrique Barrau and Jim Herron of CSU.

FINAL REPORT

Phase II-B

Revegetation of Disturbed Surface Soils in Various Vegetation Ecosystems in the Piceance Basin

By

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and

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December 31, 1974

ABSTRACT

Oil shale development in the Piceance Creek Basin of northwestern Colorado can bring about profound changes in both the vegetation and physiography of the area. These changes may have significant affects upon the wildlife population and livestock use within the basin if proper rehabilitation procedures are not followed.

Potential changes have warranted the study of species adaptability for future revegetation programs. Locations in four major vegetation types in the oil shale region were studied with respect to restoring areas where surface disturbances may occur, such as roads, pipelines, construction sites, or where the topsoil may be used to cover overburden or processed oil shale material.

The objectives of this study were to determine which native and introduced species would be best suited for revegetation projects in each vegetation zone selected. Species were selected for purposes of protecting the soil from wind and water erosion and improving the habitat for large herbivores.

Native and introduced species of grasses, forbs and browse were planted in the fall of 1972 and 1973 on favorable and unfavorable expressions in the following major vegetation zones: 1) Low Elevation Pinyon-Juniper Woodland, 2) Mid Elevation Sagebrush Shrubland, 3) High Elevation Pinyon-Juniper Woodland, and 4) Mixed Mountain Shrubland.

Two treatments of surface disturbances were applied to each expression at the four ecosystems. These treatments included: 1) vegetation removed by scraping with a minimum of soil loss and 2) plowing to a depth of 20 to 30 cm after removal of the vegetation.

Preliminary results of emergence and survival at each vegetation type appear promising for future revegetation projects. Various wheatgrasses, bromes, and green needlegrass displayed good to excellent emergence and survival at all locations. The forbs and legumes which showed the most success were the vetches, alfalfas, sweetclover, penstemons, Lewis flax, bouncing-bet, and arrowleaf balsamroot. Browse species have been slower to germinate and grow than the grasses and forbs. This has been due to dormancy, poor quality seed, and the loss of seed to birds and rodents. Browse plants which performed the best throughout most locations were Stansbury cliffrose, green ephedra, black chokecherry, antelope bitterbrush, winterfat, and yellowbrush.

Species which did best at the higher elevations included Manchar brome, mountain brome, Barton western wheatgrass, C-43 basin wildrye, sweetanise, Rocky Mountain penstemon, gooseberry-leaf globemallow, verbena, common bladdersenna, desert bitterbrush, and black chokecherry.

Species that performed best at the lower elevations included Sodar streambank wheatgrass, bouncing-bet, yellowbrush, and winterfat. Most species which displayed good emergence and survival performed equally well on both favorable and unfavorable sites.

Natural revegetation following disturbance also shows promise for reclamation provided the disturbance is not long-term and adequate seed sources and rootstock are present in the soil material that is remaining or replaced.

In general, the species present prior to disturbance were also important following both scraping and plowing. During the two years of this study, the natural stage of succession at the lower elevations appeared to be at a grass-forb stage with some annual forbs. At the higher elevations the successional stage again appeared to be in a grass-forb stage but progressing into a shrub-grass stage. Natural recovery is a slow process in the semi-arid situations but is an important factor to be considered because successional processes will be responsible for developing, at least in part, the diverse vegetative ecosystems necessary to support the complex animal populations.

INTRODUCTION

In 1918, the first full-scale processing plant, consisting of a crusher and retort, began operation near DeBeque, Colorado. By 1920 there were well over a hundred fledgling oil shale companies buying land, patenting claims, constructing retorts and selling shares. Americans have been debating the feasibility, as well as the plausibility, of shale oil as a source for fossil fuel for well over a half a century.

The oil shale boom in the early 1900's did not last long. Shale oil was not a profitable energy source as everyone initially thought and the need for shale oil was no longer present with the discovery of more adequate sources of crude oil. In the late 1960's and early 1970's, supplies of petroleum became critical. World population continually increased accompanied by a continually rising standard of living. Fossil fuel reserves were dwindling quickly, and the tremendous demand and increasing costs of crude oil in the United States resulted in an increased interest in shale oil.

Today, large scale development of vast oil reserves in the extensive shale beds of the western United States has virtually become a reality. Development will be taking place in relatively fragile environments, which can have a profound affect on landforms, vegetation, and animal life. Since the Piceance Creek Basin is the habitat for one of the largest migratory mule deer herds in the world and is one of the most productive wildlife areas in the state, it is a major recreational resource. Thus, any revegetation project carried out in this area must serve a multitude of purposes. It must reduce erosional processes, provide aesthetic beauty, restore wildlife habitats and provide the necessary food resource for domestic as well as wild herbivores in the area.

From other studies of semi-arid regions, similar to the Piceance Basin, it has been shown that many landforms under these climatic conditions are unstable and suseptible to destructive and sudden erosional processes. The revegetation of disturbed lands must depend ultimately upon the use of plants adapted to the semi-arid climate in this area. Suitable plant species must be tested and confirmed before oil shale development begins. If so, the revegetation process can be conducted quickly and confidently in order to restore the disturbed areas before undesireable changes occur.

A detailed review of pertinent literature has been included with the Phase I final report (Terwilliger, Cook and Sims, 1974), and will not be included here. The report following includes detailed descriptions of the study area, methodology involved in this field research and the results of species adaptability trials on the various ecosystems subjected to different surface disturbances over a two-year period and an evaluation of natural recovery following surface disturbances with reseeding. Summary tables are found in the body of the report and more detailed data are found in the Appendix.

DESCRIPTION OF THE STUDY AREA

The Piceance Creek Basin is located in northwestern Colorado. It is a topographic feature about 153 km long and 80 km wide. Part of this structural basin forms a distinct physiographic unit, the Roan Plateau, bounded on the east by the Grand Hogback, on the south by the Colorado River, and the Book Cliffs, on the west by Douglas and Salt Creeks and the Cathedral Bluffs, and on the north by the White River (Figure 1). The Piceance Creek oil shale area of Colorado occupies the eastern most portion of the Tavaputs Plateau, part of the Uinta Basin Section of the Colorado Plateau Physiographic Province (Schumm and Olson 1974).

The basin is located in Rio Blanco and Garfield Counties. The two principal towns in Rio Blanco County are Meeker, the county seat, with a 1971 population of 1,536, and Rangely, with a population of 1,638. The post office which bears the name Rio Blanco is located near the intersection of the county lines and the head waters of Piceance Creek. The total population of the county, as of 1971, was 4,761 (U.S.D.I. Vol. I 1973).

The major communities in Garfield County are Glenwood Springs, the county seat, with a 1971 population of 4,100, Rifle, with a population of 2,500, and Grand Valley, with a population of less than 500. The total population of the county, as of 1971 was 14,800. The Utah state line forms the western boundary of both counties (U.S.D.I. Vol. I 1973).

The Piceance Creek Basin (Figure 2a) is unique in that it has been classified as a topographic basin, a structural basin and a depositional

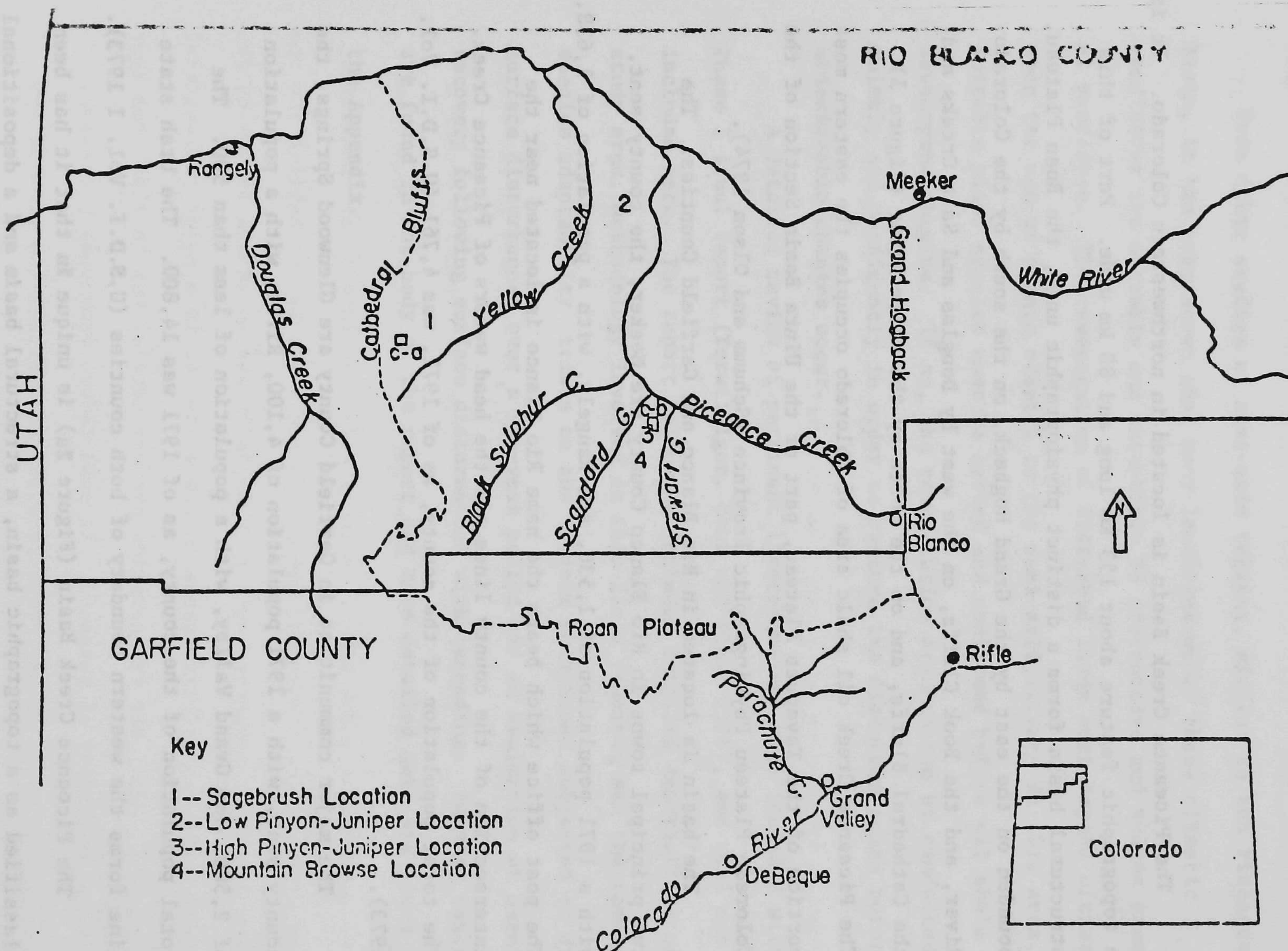


Figure 1. Map of Piceance Creek Basin and surrounding towns.

basin. Topographically, the lowest elevations, 1738 m, are situated along Piceance Creek in the center of the basin, while high ridges, up to 2745 m are around the edges of the basin. Structurally, the basin has all strata tilted toward the center of the area, thus the greatest depths to any given strata, such as that which contains the oil shale is in the center of the basin. The area was also a depositional basin slowly sinking in the center as sediment filled it, thus the thickest strata, including those richest in oil shale, are situated in the central part of the basin (Campbell et al. 1974).

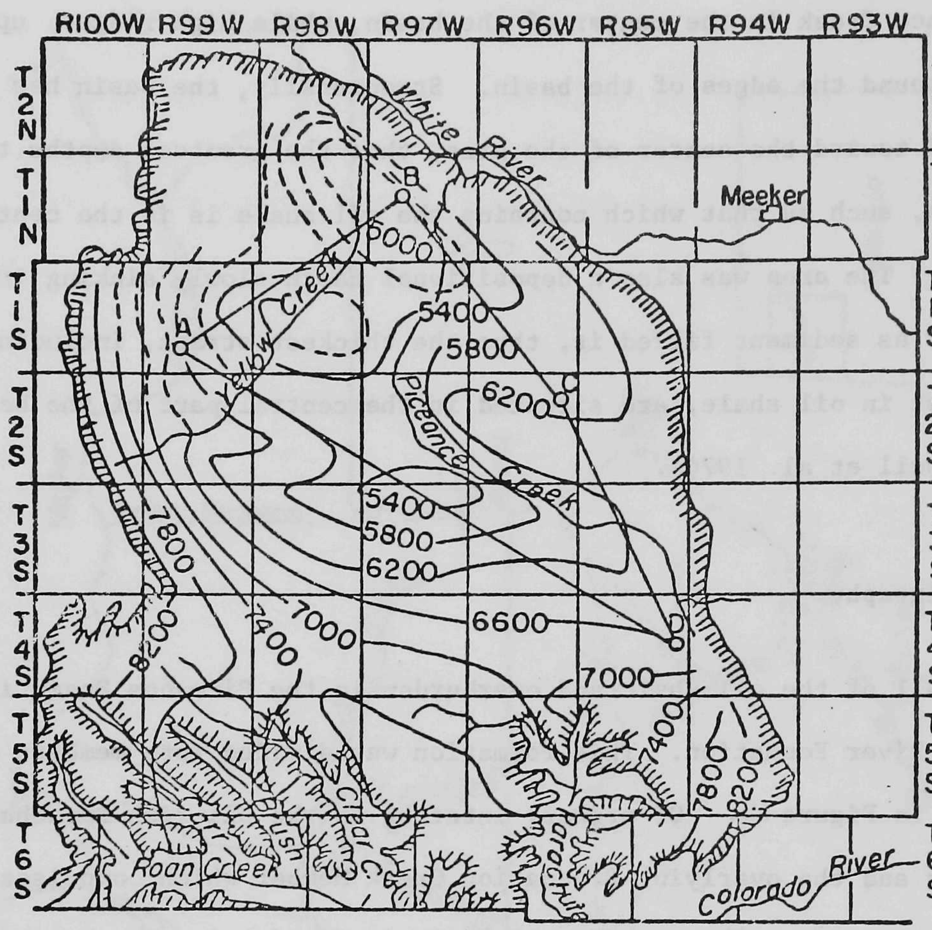
Stratigraphy

All of the oil shale and overburden in the Piceance Basin is in the Green River Formation. This formation was divided into members as shown in Figure 6b. Of primary interest is the oil rich Parachute Creek Member and the overlying Evacuation Creek Member which comprises most of the overburden. The richest oil shale is found below the Mahohany Marker in the Parachute Creek Member (Figure 2b).

Soils

Detailed soil information for the Picenace Creek Basin is very limiting. Except for a soil survey of the Little Hills Experiment Station and a few isolated surveys made for the purpose of developing ranch plans, there is essentially no detailed soil survey information available for the oil shale area (Campbell et al. 1974).

A general soil map showing soil associations is available for the area and is useful in comparing different parts of an area, or for locating



6200 Elevation above mean sea level of Mahogany marker

Approximate outline of Green River Formation

o^A Measured section

Figure 2a. Index Map showing location of measured sections and cross section (Campbell et al. 1974).

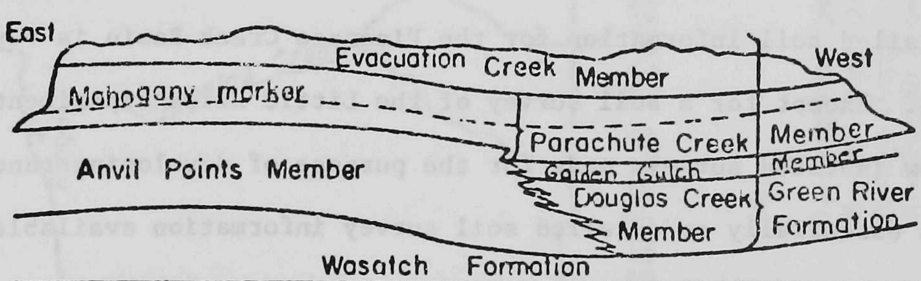


Figure 2b. Members of the Green River Formation (Campbell et al. 1974).

large tracts of land that are suitable for various uses. Such a map is not useful for on-site planning for a small area because the soils in any one association usually differ in degree and complexity of slope, drainage, texture, stoniness, infiltration, and other characteristics that affect management (Campbell et al. 1974).

Soil information that is available suggests that soils of the Piceance Creek Basin vary widely in characteristics such as depth, texture, structure, stoniness, moisture regime, temperature regime, organic matter, and in their chemical nature. The existing mapped, chemical and physical data are not adequate for defining the extent, distribution, chemical and physical properties of soils, except in a very general manner (Campbell et al. 1974).

The soil water regime refers to the presence or absence of either groundwater or of water held at tension <15 bars in the soil for various periods of the year. Soil water regime of a soil is important to revegetation work primarily because it is related to the growth potential for different plant species (Campbell et al. 1974).

The water regimes discussed by Campbell et al. (1974) include aquic, aridic and torric, ustic and udic. The aquic water regime refers to a soil which is saturated by groundwater or by water of the capillary fringe. The period in which the soil is saturated is not exactly known.

The terms "aridic" and "torric" are used to identify the same water regimes, but in different categories of the taxanomic classification. In the aridic (torric) water regime the water control section in most years is 1) dry in all parts more than half the cumulative time that the soil temperature at a depth of 50 cm is above 5^{o} C; and 2) never moist in some or all parts for as long as 90 consecutive days when the soil temperature at a depth of 50 cm is above 8^{o} C. Soluble salts will accumulate in the soil in this water regime because of little or no leaching.

Water is limiting under a ustic soil water regime, but water is present at a time when conditions are suitable for plant growth. The annual soil water condition in soils having this regime can be described as follows: The period from late September through mid-February to late April is a period of surplus moisture (where precipitation exceeds evaporation). It is during this period that some leaching could occur. From late April to mid or late June evaporation exceeds precipitation. There is sufficient water for plant growth but very little leaching occurs. During the period from mid or late June to September a water deficiency occurs. Growth and establishment of plants is very limited during this period.

The udic soil water regime implies that in most years the soil water control section is not dry in any part for as long as 90 days cumulative. In general, the udic soil water regime is common to soils found in climates that have a well distributed rainfall or have sufficient rain in the summer that the amount stored equals or exceeds the amount lost through evapotranspiration. The annual soil water condition in soils having this soil water regime can be described as follows: From mid-September to early December is considered a recharge period. From early December to late April is considered a surplus period. Leaching could occur during this period if the soil is not frozen. From late April to mid-September is a period of utilization. Very little leaching will occur during this period.

Climate

Annual precipitation in the Piceance Basin varies from approximately 30.4 cm in the extreme northwest corner to approximately 60.9 cm in the southwest corner. The area is generally classified as semi-arid (U.S.D.I. Vol. I 1973).

Slightly less than half of the precipitation occurs as snow and falls during the period of December to April. The amount of precipitation occurring during the spring season is usually very small. During the latter part of the summer, thunderstorms occasionally occur; flash floods, ranging from light to very severe, accompany the storms. Fall weather varies from fair to periods of infrequent rain storms or snow storms.

The area is subject to extreme temperature differences, with summer temperatures reaching 37.5° C, and winter temperatures dropping to a -40° C. The frost-free season varies from a period of 124 days at the lower elevations to a period of 50 days at upper elevations. The dry climate and relatively short growing season restrict cultivation to the growth of small quantities of irrigated native hay, alfalfa, corn for silage, and some small grains along Piceance Creek and the White River.

Vegetation

According to Ward *et al.* (1974) the natural vegetation in the Piceance Creek Basin can be divided into two distinct categories, the bottomlands and the uplands, based on their relative topographic position. Bottomlands, which include the valley floors and alluvial fans, are areas of erosional accumulation and areas which receive water both from precipitation and run-on. Uplands include the hillsides and ridges and are areas of erosional depletion, where precipitation is the only source of water and sometimes excessive runoff occurs.

Some of the communities described occur through the region, while others are more restricted. Plant communities of limited geographic extent are usually ignored, while communities occupying large portions of the lanscape are included. Some communities with small geographic representation are included due to their aesthetic importance (aspen) or their occupancy of critical sites (riparian woodland).

Some vegetation types vary widely from place to place while others are nearly the same everywhere found. Some 18 plant communities have been described by Ward *et al*. (1974). Due to the lack of quantitative data this listing must be considered tentative. A list of the common and scientific names referred to in the text is found in Appendix Table 1.

Land Use

Public lands in the Piceance Creek Basin are primarily used as a watershed, grazing by domestic livestock, wildlife habitats, areas for limited gas production, and outdoor recreation areas. These uses have not changed appreciably in recent years. The public domain lands are all included in two grazing districts administered under the Taylor Grazing Act. About 60,000 authorized animal unit months of forage use are distributed among 45 permitees (U.S.D.I. Vol. I 1973).

Cattle graze yearlong on about 50 percent of the area and both cattle and sheep graze the remainder of the area during spring, summer and fall. Mule deer and elk are found throughout the area with the estimated mule deer herd being approximately 20,000.

Land ownership within the Piceance Creek Basin at the present time is divided as follows: Bureau of Land Management--64 percent, State--3 percent, and private land--31 percent.

Future land use may bring about more profound changes than have been experienced since man has entered the basin. Oil shale development will require the use of land under three categories: 1) that associated with urban development, 2) that associated with utility corridors and the expansion of the roadway system between urban areas and the plant sites, and 3) that land associated with the development of the plant and mining areas.

METHODS AND MATERIALS

Selection of Plots

During the summer of 1972 four major vegetation types were selected in the Piceance Creek Basin according to relative productivity and percent of total land area occupied. The four vegetation types included: 1) Mid Elevation Big Sagebrush Shrubland, 2) Low Elevation Pinyon-Juniper Woodland, 3) High Elevation Pinyon-Juniper Woodland, and 4) Mixed Mountain Browse (Shrubland). The above numbers correspond to those shown on Figure 1. A research plot was chosen in each vegetation type according to vegetation cover, slope and aspect. Each location chosen includes both an unfavorable harsh site and a favorable site in order to get a better representation of the natural ecosystems throughout the basin. The favorable sites were primarily level in slope with relatively high vegetation cover and production. The harsh sites were either a south, west or northwest exposure with steeper slopes and relatively low plant production and cover.

Experimental Design and Plot Preparation

Each location was set up in a completely randomized split-split plot design with two replications on each site along with two treatments (Figures 3, 4, 5 and 6). After the experimental design was determined treatments were then applied to each site. The two surface disturbances that were applied included: 1) vegetation removed by scraping (with a D-8 caterpillar) with a minimum of topsoil loss and 2) plowing to a depth of 20 to 30 cm after removal of the vegetation (with a rubber tired

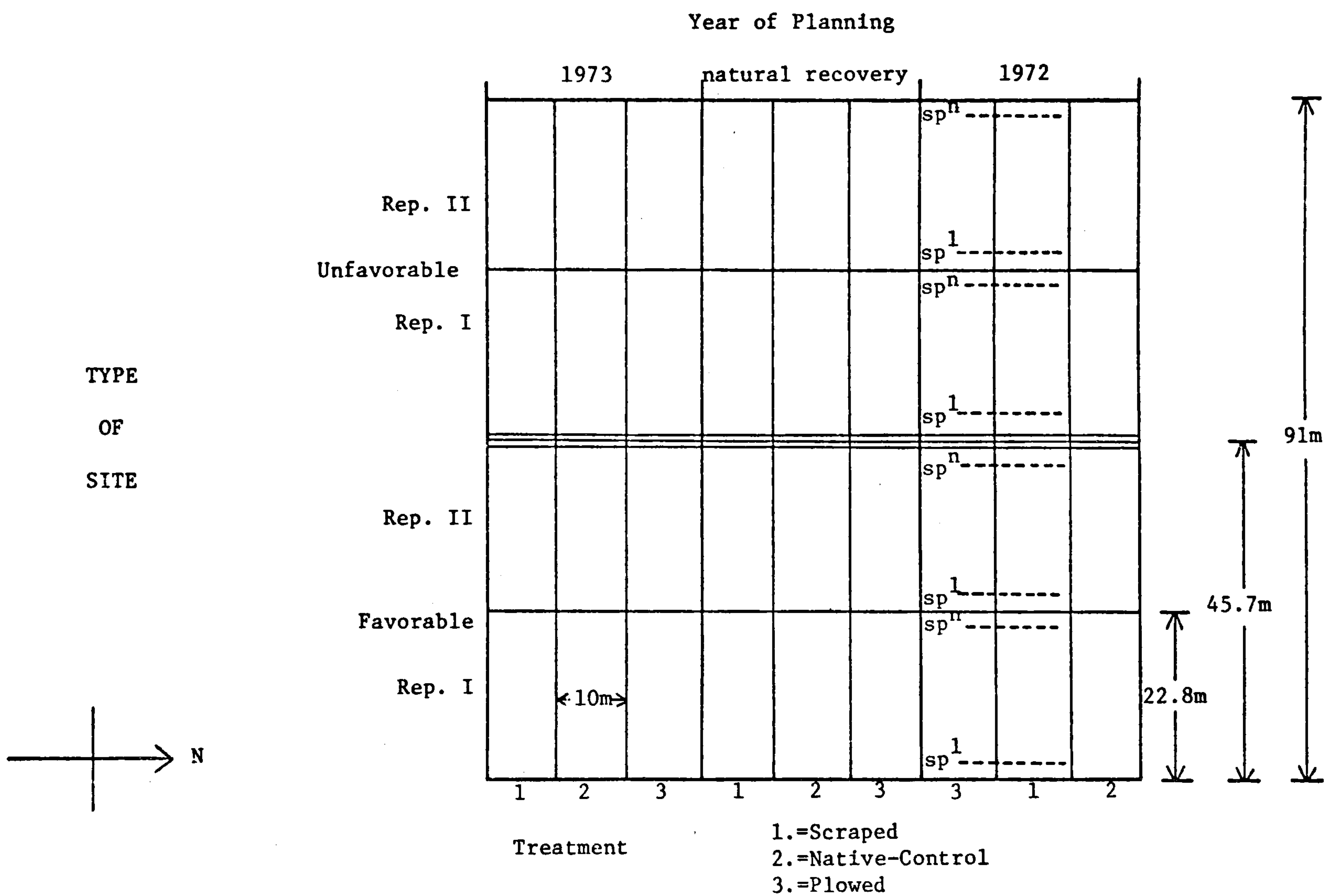


Figure 3. Experimental design for sagebrush location.

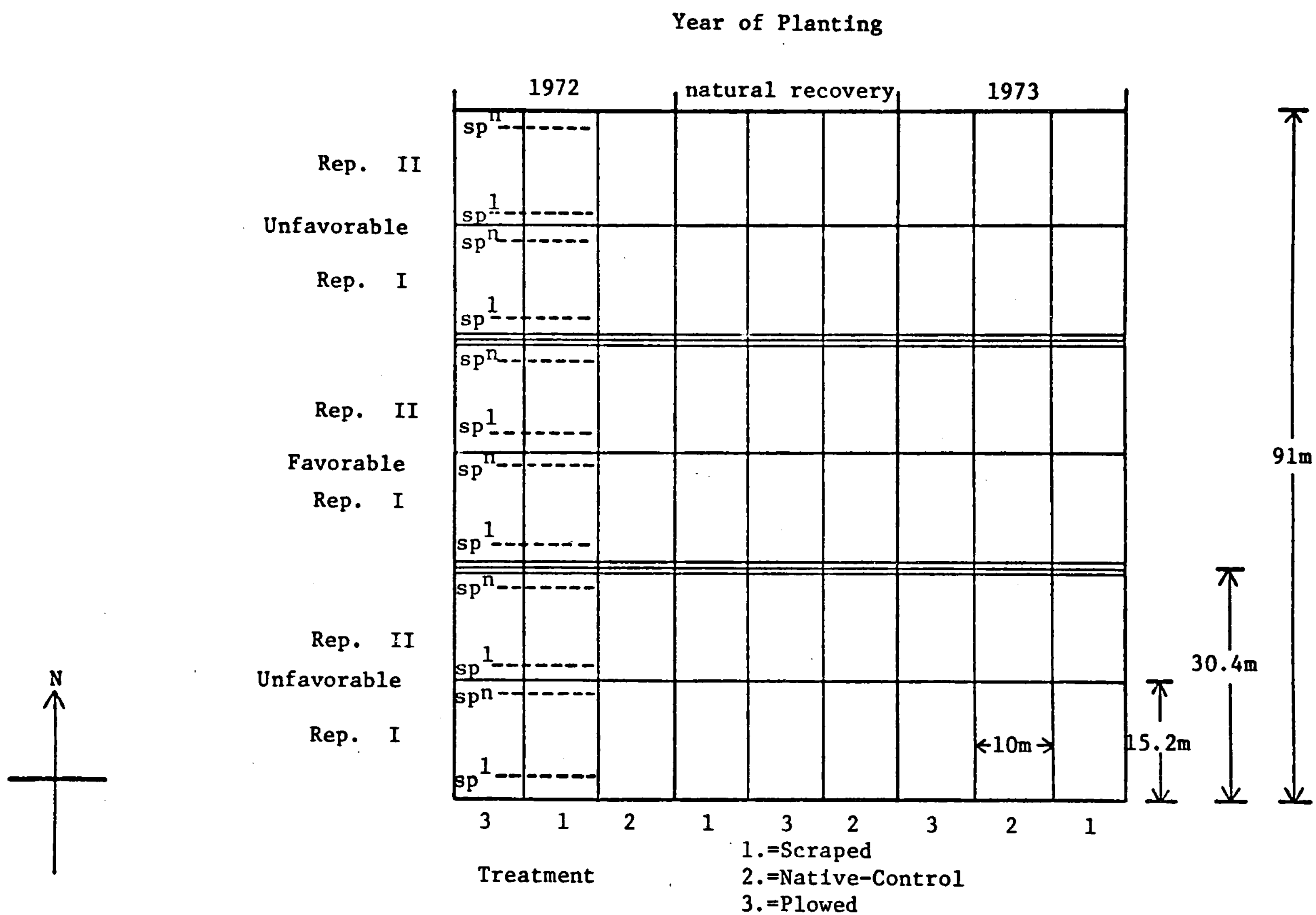


Figure 4. Experimental design for low elevation pinyon-juniper location.

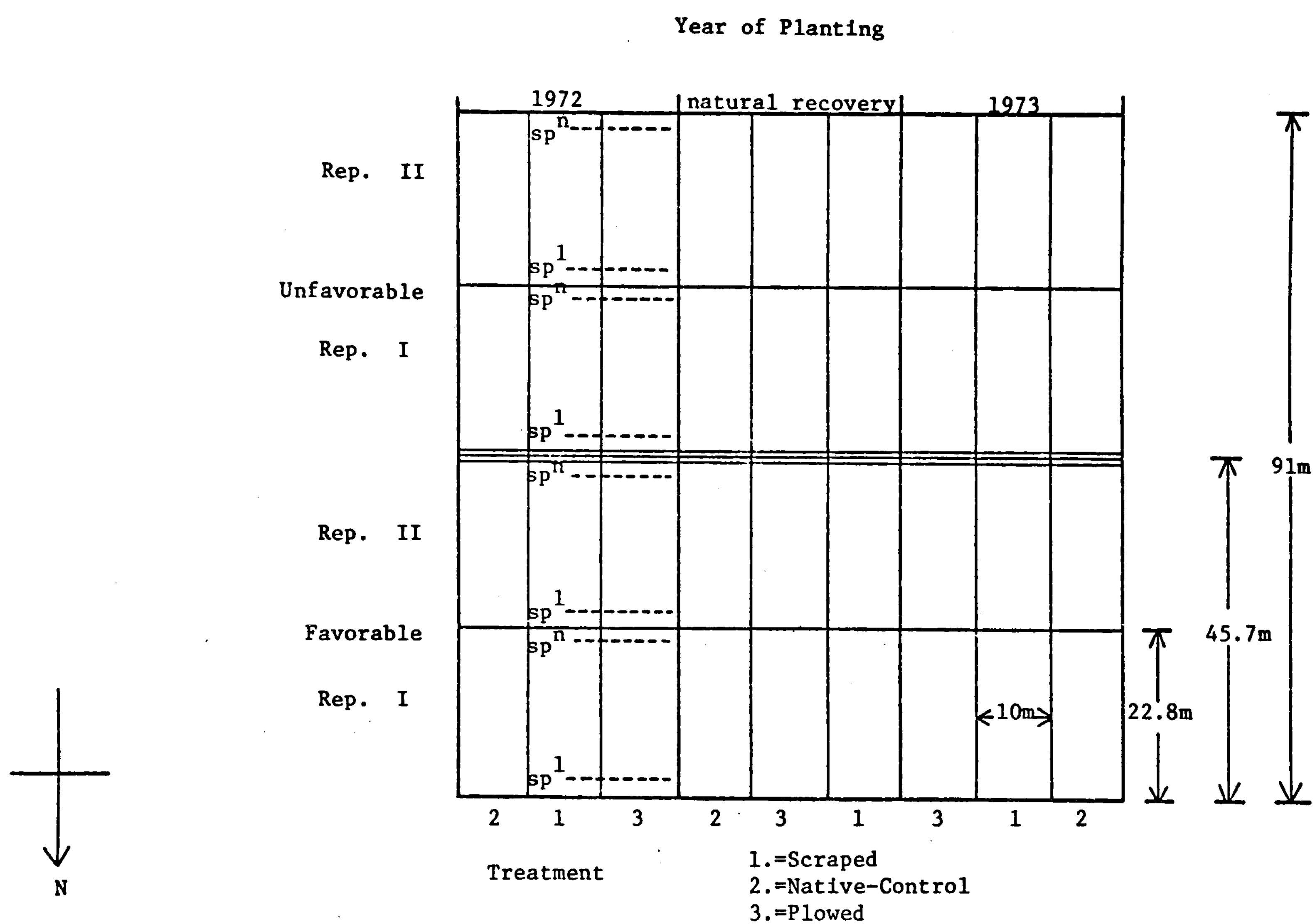


Figure 5. Experimental design for high elevation pinyon-juniper location.

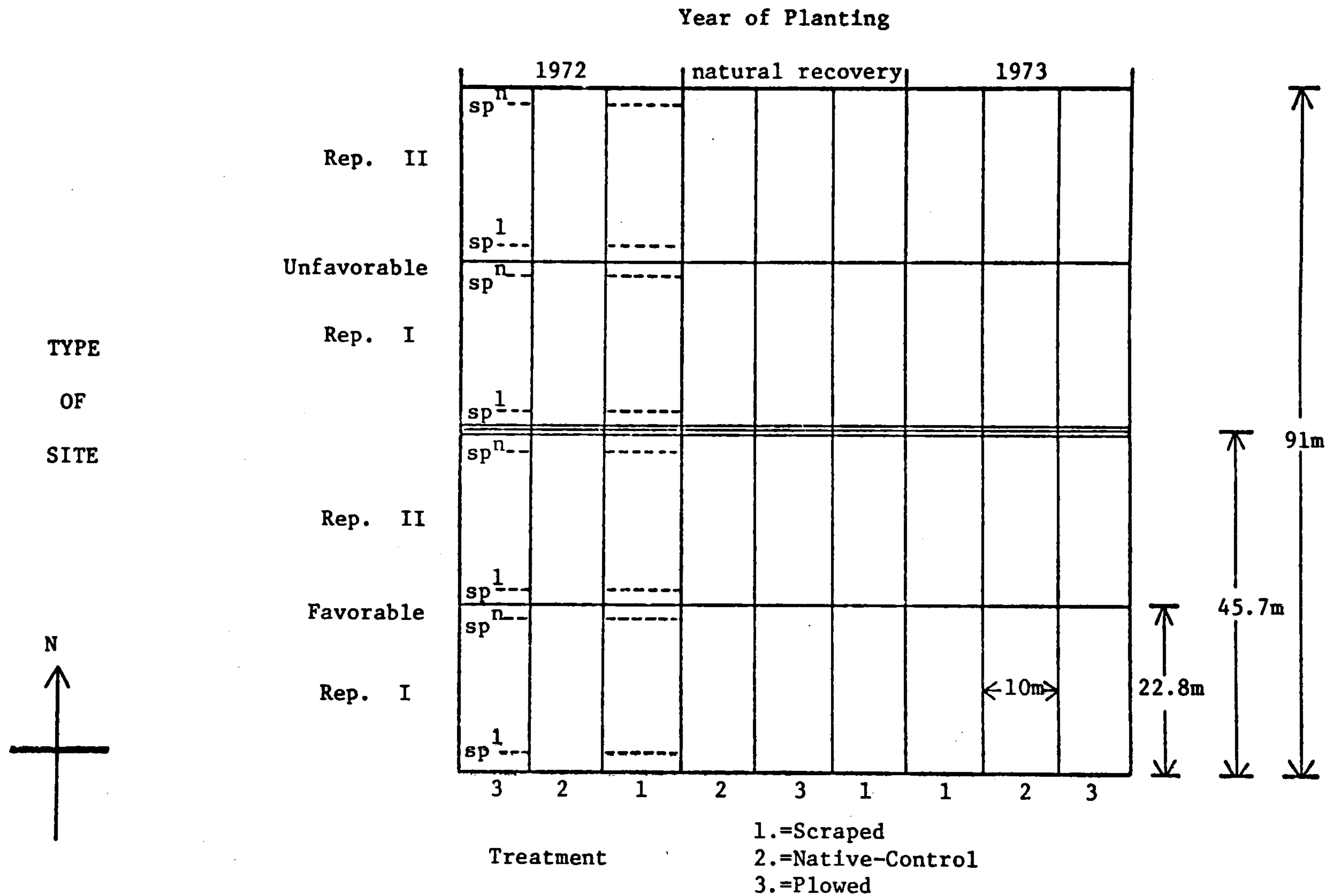


Figure 6. Experimental design for mountain browse location.

tractor). The purpose of the two treatments was to determine which one would aid germination, growth and survival.

The final plot preparation included the construction of a four strand barbed wire fence around each location. Each plot was fenced off during the summer of 1973 in order to exclude both cattle and wild horses. A deer proof fence was initially considered for each location, but a lack of funds prevented construction.

Species Selection

Seed for each species was purchased from various seed companies during the summer of 1972. Some species were obtained from the Soil Conservation Service's Plant Materials Center in Los Lunas, New Mexico, while the remaining species were acquired from private seed companies in Colorado, Utah, Idaho and Kansas.

An emphasis was placed on native species when ordering seed. As many native grasses, forbs and browse as possible were obtained, along with introduced species that were found to be superior in past seeding trials in environments similar to the Piceance Basin (Appendix Table 2). Native species were emphasized primarily because the information related to seeding methods, along with survival and production of native species was limited. The use of native species in revegetation projects, in the place of introduced species, should also accelerate the successional process in order to reach a self sustaining ecosystem more rapidly.

Planting

Each location included adequate space, approximately 0.8 hectare (2 acres), for two separate seedings, a natural recovery area, and native control zones. The first seeding took place during September and October of 1972 and the second seeding during September 1973. The two treatments were re-applied in August 1973 before the second seeding took place in order to remove the invading annual and perennial species.

Seeding was done by hand into six meter rows at a depth of 1.27 cm. Approximately 150 seeds were planted per linear meter. The first two seedings utilized individual species in each row except for one mixture used during the second seeding in 1973. Future seedings will place more emphasis on mixtures.

A rather high seeding rate was used primarily because the germinability of the seed was unknown. It was felt that a high seeding rate would assure some germination in the seeding trials. In the fall of 1973, after the second seeding took place, germination tests were conducted on all seeds planted in 1972 and 1973 (Appendix, Table 3). The testing for grasses and forbs was done in accordance with the Rules For Testing Seed (Association of Official Seed Analysts 1970). Browse species, however, were not tested in the same manner because of a dormancy factor which had to be overcome. Therefore, a standard tetrazolium test was conducted on all browse seeds to determine viability.

Emergence And Survival

Information was collected during the spring, summer and fall of the first growing season (1973) and again in the summer of the second growing season (1974). The data collected in 1974 on the second seeding were for the first growing season. Qualitative and quanitative data were collected in 1973, while only qualitative data were collected in 1974 because of a lack of sufficient time.

Each seeded row was observed and rated on a scale of 0, 1, 2, 3, or 4, which represented none, poor, fair, good, and excellent emergence or survival, respectively. This procedure was used at each location to gather qualitative information concerning emergence during the first growing season and emergence and survival during the second growing season. This information was collected for the first seeding in May 1973, June 1973, September 1973, June 1974, and July 1974. Qualitative data were also collected for the second seeding in June and July 1974.

Seedlings were counted during the first growing season (August 1973) to acquire quanitative information on emergence. Sample units for counting seedlings consisted of four sections, 30.48 cm in length, along each seeded row. A tape measure was placed along each row, four sections were chosen, and seedlings were counted.

Natural Recovery

The center one-third of each location was scraped and plowed, and then left for natural revegetation to take place. Because of the limited data available on natural recovery from surface disturbances in the Piceance Basin, information collected here will be essential in revegetation programs.

Double sampling procedures were conducted, using a 0.1 m^2 Daubenmire (1959) plot in order to collect canopy cover and biomass data on the natural recovery and control zones (Daubenmire 1959). Within each favarable site 33 random sample points were used to gather this data. Cover and biomass information was collected by species and then analyzed as described by Daubenmire (1959). This data was collected in August 1973, June 1974 and August 1974. Canopy cover on the native areas has been included in the section on results and discussion. The other information on biomass and canopy cover on the natural recovery areas has not been included because the main objective of this study was to determine species adaptability from artificial revegetation.

Methods of Analysis

The statistical programs used in this analysis included chi-square for the qualitative data and analysis of variance for the quantitative data. Chi-square summary table were developed by cross tabulating each species with each location, site, and treatment. Raw frequencies and percentages were determined for each tabulation to determine how each species performed at a particular location and on a certain site and t reatment.

An analysis of variance program was used to analyze the quantitative data and then a T test was used to determine significant differences at the .01 and .05 level. The following formula was used:

$$\left| \bar{X}_1 - \bar{X}_2 \right| > t_f^{\alpha} \sqrt{s^2 \quad (1/n_1 + 1/n_2)}$$

Levels of significance were calculated for each species across each location, across each treatment, for sites within locations, treatments within locations, and treatments within sites within locations.

Precipitation and Soil Information

Weighing rain gauges were constructed in October 1972 out of steel pipe with an inside diameter of 20.3 cm. The rain gauges placed at the lower elevations were 0.9 m tall, while the gauges placed at the higher elevations were 1.2 m tall. Each gauge was set up by adding .23 liter of water, .23 liter of oil and .94 liter of antifreeze to prevent evaporation and freezing during the year. Each gauge was then weighed periodically during the summer and winter to determine centimeters of precipitation. These gauges were not as accurate as a standard rain gauge, but they did give a good representation of the precipitation in each area.

Along with the other information collected, a soil survey was conducted at each location by the Soil Conservation Service in Meeker, Colorado. The morphology of each soil was described and then classified according to tentative taxonomic units (Appendix, Table 4). This information has been useful in explaining some of the differences which existed in the vegetation composition and growth on different sites.

RESULTS AND DISCUSSION

Each plot will be described in detail with respect to geographic location, precipitation, native vegetation, soil characteristics, and species evaluation. Species evaluation will receive the most emphasis and will include a narrative description of the best species along with summary tables of the data collected in 1973 and 1974.

Mid Elevation Sagebrush Location

Description of Location

The sagebrush location which is situated at an elevation of 1,988 m is located on the southwestern portion of the 84 Mesa just east of the C-a federal lease site. The legal description is: T. 1S., R. 98W., Sec. 19, SW¼, SW¼, NW¼.

The average annual precipitation for this location varies from 33 cm to 38 cm. Approximately 41.9 cm were received at this location during a 14 month period in 1972 and 1973 (Appendix, Table 5). It is important to keep in mind that the rain gauges that were used were not standard rain gauges. Therefore, it is believed that anywhere from 10 to 40 percent of the precipitation could have been missed due to wind action and other physical effects.

The natural vegetation was dominated by big sagebrush with Douglas rabbitbrush, shadscale, fringed sage, winterfat and greasewood as common shrub components. Indian ricegrass, needle-and-thread, western wheatgrass, beardless wheatgrass, Junegrass, squirreltail, and cheatgrass occur throughout the understory. Forb species that were recorded during sampling procedures included scarlet globemallow, wildbuckwheat, milkvetch, phlox, nodding onion, cryptantha, goldenweed and townsendia.

Within the sagebrush location there were two distinct aspects that were seeded. The first aspect was west facing with a 4 to 1 slope (Figure 7). The soil on this exposure was calcareous with the A-11 horizon having a field determined pH of 8.4 and the CR horizon having a pH of 9.4 (Appendix, Table 4). The A-11 horizon was a gravelly fine sandy loam with a platy surface crust one to two cm thick. The C-1 horizon was a weathered channery sandstone with lime coatings on the underside, turning into loamy sand. The natural vegetation on the west slope was sparce with the ground cover being approximately 41 percent. The dominant species on this aspect were Indian ricegrass, needle-and-thread, western wheatgrass, goldenweed, wildbuckwheat, big sagebrush, and winterfat. Of this 41 percent, western wheatgrass constituted approximately 8 percent of the ground cover, Indian rice-grass 5, goldenweed 5, big sagebrush 4, needle-and-thread 4, wildbuck-wheat 3, and winterfat 2 percent of the canopy cover.

The second exposure was a level terrain (less than 5 percent) lying adjacent and directly east of the west aspect (Figure 8). This site was moister than the west aspect and had a deeper and less calcar-eous soil. The A-11 horizon was a loam with the surface crusted with moderate coarse platy structure and had a field determined pH of 8.0. The C-1ca horizon was a strongly calcareous heavy loam with a pH of 9.4 and the CR horizon was a weathered sandstone with a pH of 9.2.

The ground cover on the level exposure was approximately 60 percent. The dominant species were big sagebrush, displaying 22 percent of the

Figure 7. Sagebrush Location, 4 to 1 west facing slope.

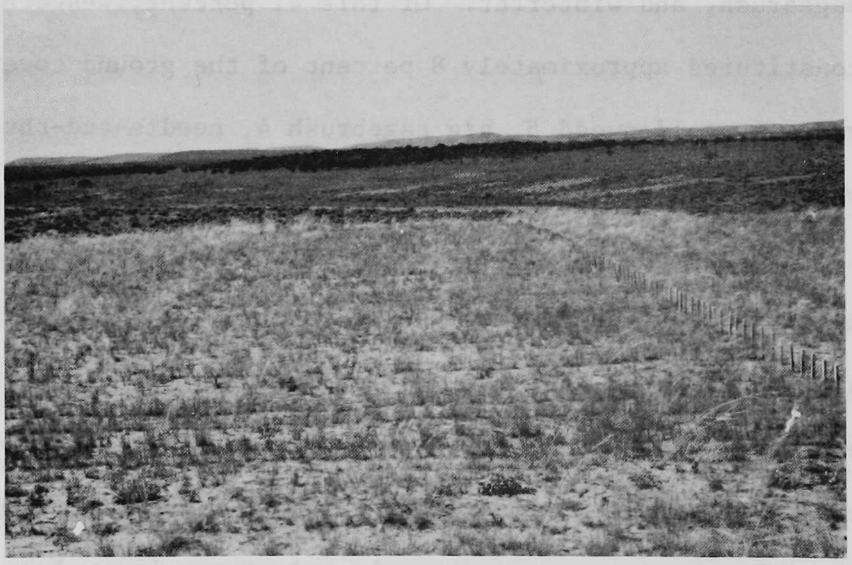


Figure 8. Sagebrush Location, level sloping site.

ground cover, cheatgrass 12, scarlet globemallow 5, phlox 4, needle-and-thread 3, western wheatgrass 3, and Junegrass 2 percent canopy cover.

Species Evaluation

Of the 66 species seeded during 1972 at the sagebrush location, there were 25 grasses, 18 forbs, and 23 browse. According to chi-square summary tables the grasses had the largest number of species which showed good to excellent emergence and survival.

Grasses

During the 1974 growing season, eleven grasses showed good to excellent emergence and survival 20 months after seeding. The same eleven species also displayed good to excellent emergence eight months after seeding took place (Table 1).

Nordan crested wheatgrass which is a long-lived perennial bunchgrass introduced from Siberia has been a highly palatable and nutritious species to all classes of livestock (Figure 9). This species has shown significantly better emergence ($P<.01$) on the level more favorable area than on the dryer west facing aspect (Appendix, Table 16). Although the emergence of this species was different, the survival of the plant was the same on both sites and both treatments during the second growing season (Table 1).

Critana thickspike wheatgrass is a perennial grass with extensive creeping underground rootstocks. It is native to Colorado and furnishes fair forage for all classes of livestock. This wheatgrass has also shown significantly better emergence ($P<.01$) on the favorable site compared to the unfavorable west aspect.

Table 1. Summary table for the adaptability of the best grasses, forbs and browse seeded on two different aspects at the sagebrush location. Data collected in 1973 and 1974.

Species	1973 Data Adaptability on different aspects* Level slope	1973 Data West slope	1974 Data Adaptability on different aspects** Level slope	1974 Data West slope	Remarks
Grasses					
Nordan crested wheatgrass	4	4	4	4	bunchgrass, introduced, highly palatable and nutritious
Critana thickspike wheatgrass	4	3	4	3	sod-former, native, fair forage for livestock
Jose tall wheatgrass	4	4	4	4	bunchgrass, introduced, salt-tolerant
Amur intermediate wheatgrass	4	3	4	4	sod-former, introduced, highly palatable
Oahe intermediate wheatgrass	4	4	4	4	sod-former, introduced, highly palatable
Sodar streambank wheatgrass	4	2	4	3	sod-former, native, unpalatable
Siberian wheatgrass	4	4	4	4	bunchgrass, introduced
Luna pubescent wheatgrass	4	4	4	4	sod-former, introduced, very productive on severe sites
Mountain brome	4	3	4	3	bunchgrass, native, short-lived perennial
Regar meadow brome	4	4	4	4	bunchgrass, introduced
Green needlegrass	4	4	4	4	bunchgrass, native, good forage value
Forbs					
Madrid yellow sweetclover	4	4	2	3	rapid growing biennial, introduced
Bouncing-bet	4	3	4	2	introduced, rhizomatous
Utah sweetvetch	3	2	3	3	native legume, produces abundant forage
Lewis flax	2	1	4	3	native, grows on well drained soils
Rhizoma alfalfa	3	1	3	3	introduced legume, rhizomatous
Rocky Mountain penstemon	3	0	4	2	native, good forage value

Table 1 Continued.

Species	1973 Data Adaptability on different aspects* Level slope	 West slope	1974 Data Adaptability on different aspects** Level slope	 West slope	Remarks
Browse					
Yellowbrush	1	1	4	3	native, used lightly by livestock and big game
Stansbury cliffrose	1	1	3	3	native, broad-leaved evergreen, grows well on severe sites
Green ephedra	2	3	3	4	native, evergreen, moderate to high palatability
Winterfat	2	3	4	4	native, drought resistent, highly palatable
Antelope bitterbrush	2	2	3	3	native, highly palatable

* Emergence ratings: 0--none, 1--poor, 2--fair, 3--good, 4--excellent.

** Emergence and survial ratings: 0--none, 1--poor, 2--fair, 3--good, 4--excellent.

Figure 9. Left to right: Rocky Mountain penstemon, Nordan crested wheatgrass, and Regar meadow brome at Sagebrush Location.

Figure 10. Left to right: Jose tall wheatgrass and Green needlegrass at Sagebrush Location.

Emergence and survival of the plant was similar on the two treatments.

Jose tall wheatgrass is an improved variety of tall wheatgrass and has been a very vigorous quick growing grass during this study period (Figure 10). This species is a perennial bunchgrass which performed equally well on both favorable and unfavorable aspects and on both the plowing and scraping. This species has also been more palatable and more nutritious in late spring and early summer than crested wheatgrass.

Amur and Oahe intermediate wheatgrass, like crested wheatgrass, were introduced from Russia and nearby countries from a climate similar to Colorado's Mountain Browse and Pinyon-Juniper types. Intermediate wheatgrass is a sod-forming grass which has shown excellent emergence and survival at the sagebrush location.

Both varieties have shown similar emergence and survival at this location (Table 1). Significant differences were not measured between either sites or treatments. Oahe intermediate wheatgrass has shown slightly better emergence than Amur, but not at a statistically significant level.

Sodar streambank wheatgrass, which is a native rhizomatous species, has shown similar emergence on both treatments and sites. Survival on the other hand was slightly better on the level terrain than on the west aspect (Table 1). The level area had an average rating of four, while the west aspect had an average rating of three. Survival was also slightly better on the plowed treatment.

Siberian wheatgrass is another introduced species from Siberia. This species is a bunchgrass and has demonstrated excellent emergence

and survival at the sagebrush location. During emergence there was a statistically significant difference ($P<.05$) between the plowed and scraped treatments on the favorable aspect.
Plowing aided emergence, but these treatment differences disappeared over time. Siberian wheatgrass has displayed excellent survival throughout this location with little differences between treatments and sites.

Luna pubescent wheatgrass like crested wheatgrass was introduced from Russia and is similar to intermediate wheatgrass except its seedheads and foliage have much more pubescence, and it is generally a more vigorous sod-former (Plummer 1968). Pubescent wheatgrass is less palatable than intermediate, but it is more productive and persistent on severe sites. Luna pubescent wheatgrass was one of the best grass species at the sagebrush location. It performed equally well on both sites and on both treatments during emergence and survival.

Mountain brome is a short-lived perennial bunchgrass that is among the best forage grasses on the western ranges (Figure 10). This species is common at higher elevations but is not expected to survive very long at this location. Emergence was the same throughout this location while survival was slightly better on the favorable area and had a better stand of brome grass than did the west aspect (Table 1).

Regar Meadow brome is an introduced perennial bunchgrass that has displayed similar emergence and survival throughout this location (Figure 9).

Figure 10. Mountain brome at Sagebrush Location.

Figure 11. Utah sweetvetch at Sagebrush Location.

Statistically this species has performed the same on both the plowing and scraping and on the favorable and unfavorable sites. Regar meadow brome is also adapted to slightly higher elevations and may be a short-lived species at the sagebrush location.

Green needlegrass is a native perennial bunchgrass sometimes referred to as green porcupinegrass (Figure 9). Green needlegrass is regarded as having good forage, being one of the first grasses of its association to start spring growth and remaining green until late in the season, thus supplying succulent forage over a long period. It performed excellently on both the plowing and scraping and on the favorable and unfavorable aspects without any significant difference. This species is native to lower elevations up to 2745 meters and therefore should continue to do well at the sagebrush location.

Forbs

The forb and legume species planted at the sagebrush location did not perform as well as the grasses. Only two species showed good to excellent emergence in 1973, while four species displayed good to excellent emergence and survival in 1974 (Table 1).

Madrid yellow sweetclover is a rapid growing, deep rooted biennial that grows and maintains itself best on disturbed areas (Plummer 1968). Madrid yellow sweetclover produces considerable palatable forage for big game through the first two years after seeding. Its continued occurrence then depends on whether seed has matured and shattered. This species had good emergence in 1973, but declined slightly during the next year (Table 1). It performed equally well under all conditions in 1973, but displayed a lower survival rate on the scraped treatment in 1974.

Bouncing-bet, introduced from Caucasia has underground spreaders and is especially useful for stabilizing eroding sites on the Mountain Browse and Pinyon-Juniper vegetation types (Plummer 1968). This species is also preferred by deer because of its heavy seed clusters and considerable green growth. Bouncing-bet had good to excellent emergence in 1973 within the entire location. Survival in 1974 was excellent on the favorable area, but only fair on the west aspect (Table 1).

Utah sweetvetch is a native legume which produces abundant forage that is highly palatable to big game and domestic livestock (Figure 11). This species occurs widely throughout the Pinyon-Juniper, Mountain Browse and Sagebrush vegetation types. Utah sweetvetch performed equally well on both the plowing and scraping and on both sites. Emergence during 1973 was rated as fair to good, while emergence and survival in 1974 were rated as good (Table 1).

Lewis flax, a native forb, grows on well drained soils in almost all vegetation types in the Piceance Basin (Figure 12). It produces abundant stems, flowers and seeds which are sought by both big game and game birds. Lewis flax has shown poor emergence during the first growing season and good to excellent emergence and survival during the second growing season (Table 1). It performed somewhat better on the level slope than on the west slope, while the two treatments were similar.

Rhizoma alfalfa is an introduced legume which is well adapted for seeding on disturbed lands. Its underground stems are useful in

Figure 12. Lewis flax at Sagebrush Location.

Figure 13. Yellowbrush at Sagebrush Location.

stabilizing eroding sites and producing rapid ground cover. Emergence has been slow on the west aspect, while survival has been good on both aspects with the level area displaying a slight advantage (Table 1). No significant differences existed between sites or treatments.

Rocky Mountain penstemon is a native perennial which is found primarily in the Pinyon-Juniper and Mountain Browse vegetation types (Figure 13). Its leaves remain green throughout the winter and provide good forage for big game species when it has not been covered by snow. This species has shown consistently better emergence and survival on the level more favorable area compared to the west slope (Table 1). Statistically there was a significant difference ($P<.05$) between sites, but not between treatments in 1973.

Browse

The browse plants were the slowest species to emerge at the sagebrush location. Only five species displayed good to excellent emergence and survival during 1974 (Table 1). A few species showed fair emergence in 1973, but only green ephedra and winterfat were rated as being good on only two replications. The low emergence rating is due primarily to the poor quality of seed in some instances and the effects of dormancy in others. Low seedling emergence is also a direct result of the loss of seed to birds and rodents during the fall and winter after seeding.

Yellowbrush is a low woody-based native perennial, belonging to the rabbitbrush (*Chrysothamnus*) genus of the aster family (*Compositae*) (Figure 13). This species increases in abundance as more palatable species are depleted by overgrazing. It is grazed lightly by cattle and sheep in early spring and moderately by cattle, sheep and horses in the late fall. Deer browse it lightly both summer and winter and elk eat it in the winter (U.S. Forest Service 1937).

Yellowbrush showed excellent emergence and survival in 1974. It performed equally well on the two treatments within the favorable area, but performed better on the plowed treatment on the west aspect than on the scraped treatment.

Stansbury cliffrose is a native broadleaved evergreen that often grows as tall as six meters, even on severe sites (Plummer 1968). It hybridizes readily with antelope and desert bitterbrush and is an excellent browse species on winter ranges. Cliffrose is a common species in big sagebrush types in Utah and grows fairly rapidly and naturally increases well on raw soils.

Stansbury cliffrose was rated good with respect to emergence and survival in 1974. Qualitatively it did not perform any differently on the west aspect, but it did show a slight difference in replication 2 on the favorable aspect. Plowing and scraping supported similar results throughout the location. This species should be well suited for developing a good cover on roadcuts and other exposed areas.

Green ephedra is an evergreen, native to the Piceance Basin, that varies in height from 50 cm to 1 m. Ephedra is a geologically ancient genus which inhabits dry open sites in valleys and hillsides, principally in the Sagebrush and Pinyon-Juniper zones. Green ephedra is moderately palatable to all classes of domestic livestock as well as deer. It is slightly grazed on the summer range, but on the winter range, where it chiefly occurs, the younger stems are eaten with relish (U.S. Forest Service 1937).

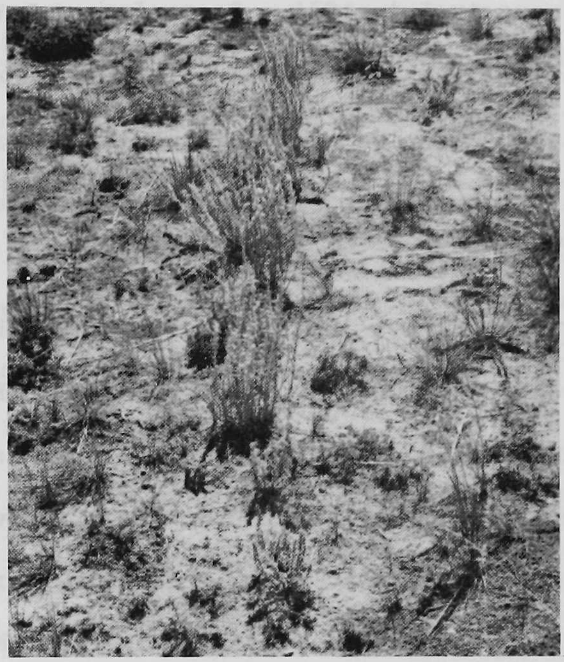


Figure 14. Winterfat at Sagebrush Location.

Figure 15. Antelope bitterbrush at Sagebrush Location.

Green ephedra was one of the fastest browse species to emerge and has shown good survival in 1974. It performed better on the west aspect in both 1973 and 1974 (Table 1). This species is well adapted to the Sagebrush vegetation type and should perform well in future rehabilitation programs. No significant differences were recorded during the first growing season.

Winterfat is a native low stature shrub which is grazed by all classes of livestock as well as by deer and elk (Figure 14). It is remarkably resistant to drought because of its deep taproot and numerous extensive lateral roots (U.S. Forest Service 1937). Winterfat is established easily and grows well on calcareous soils in the Salt-Desert Shrub, Sagebrush, Pinyon-Juniper and Mountain Browse vegetation types.

Winterfat showed the best growth and survival of all the browse species seeded at this location. It performed well throughout the lcoation, showing no difference between sites or treatments. It is highly recommended for revegetation work because of its high forage value, quick growth, and drought resistant characteristics.

Antelope bitterbrush, a native shrub, is found principally on well drained soils in the Sagebrush, Pinyon-Juniper and Mountain Browse vegetation types (Figure 15). The palatability of bitterbrush is usually good to excellent, and it is highly preferred by both cattle and sheep and big game species.

Antelope bitterbrush was rated good on both the favorable and unfavorable sites within the sagebrush location in 1974 (Table 1). Emergence in 1973 was slow, but one year later the species showed good emergence, growth and survival. Significant differences in treatments or sites were not recorded in 1973.

Selected Species

Preliminary results have shown that the above species would be the best and most productive species to seed on disturbed areas in the Sagebrush vegetation type within the Piceance Basin. Depending on how the land would be used after reclamation, a mixture of the best grasses, forbs and browse would provide abundant forage for domestic livestock and big game species, and also establish good ground cover to stabilize eroding soils.

If the reclaimed land in the Piceance Basin were used strictly for domestic livestock grazing or agricultural purposes the use of introduced and native species may be the way to ascertain this goal. On the other hand, if public demand is oriented more towards a natural condition, the use of only native species would be the answer.

The native grasses that have been recommended at this location included Critana thickspike wheatgrass, Sodar streambank wheatgrass, mountain brome, and green needlegrass. Native forbs and legumes which had superior emergence and survival during the second growing season included Utah sweetvetch, Lewis flax and Rocky Mountain penstemon. Finally, the native browse species that have been recommended for the Big Sagebrush vegetation type included yellow-brush, Stansbury cliffrose, green ephedra, winterfat, and antelope bitterbrush. These species all had good to excellent emergence and survival during the second growing season and would be recommended for revegetation work in this vegetation zone.

Low Elevation Pinyon-Juniper Location

Description of Location

The low elevation pinyon-juniper location is situated at an elevation elevation of 1,952 meters along the Yellow Creek jeep trail, west of Piceance Creek. The legal description is: T. 1N., R. 97W., Sec. 20, NE¼, SE¼, SE¼.

The average annual precipiation for this location will again vary from 33 cm to 43 cm. Approximately 49 cm were received here during a period of 14 months in 1972 and 1973 (Appendix, Table 5). This was an unusually high amount of precipitation and one must also take into consideration extremes occurring in the other direction also.

The natural vegetation was dominated by pinyon pine and Utah juniper, with the understory composed primarily of western wheatgrass, Indian ricegrass, aster, goldenweed, phlox, Lewis flax, evening primrose, winterfat, mountain mahogany, serviceberry, Douglas rabbitbrush, and snowberry.

The low elevation pinyon-juniper location was composed of three separate aspects or expressions. The first aspect was a 3 to 1 south facing slope with approximately 18 percent ground cover (Figure 16). The second aspect was a 4 to 1 north facing slope (Figure 17) and the third was the rounded ridge top lying between the north and south aspects (Figure 18). The soil was similar throughout the location with the A-1 horizon being zero to three cm thick and composed of a channery loam with a field determined pH of 8.6. The C-1 horizon was a channery silt loam with a pH of 8.8, while the CR level was a

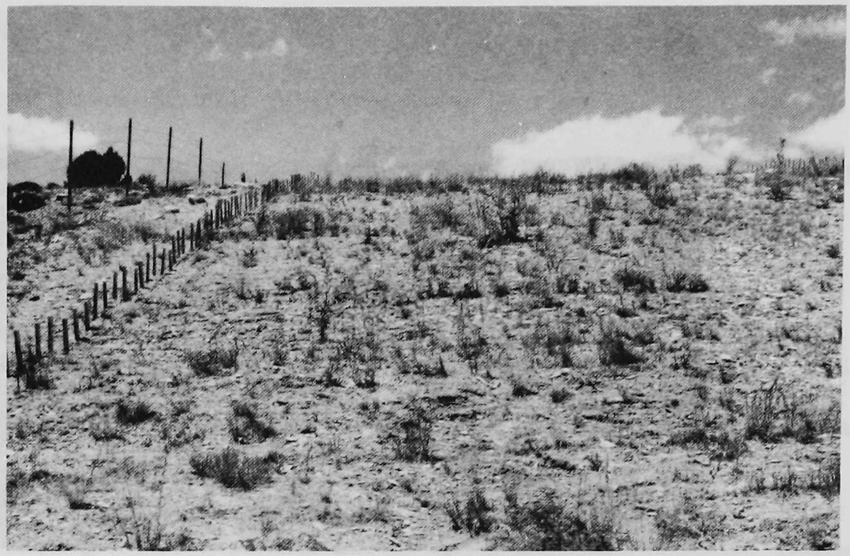


Figure 16. Low Elevation Pinyon-Juniper Location, 3 to 1 south facing slope.

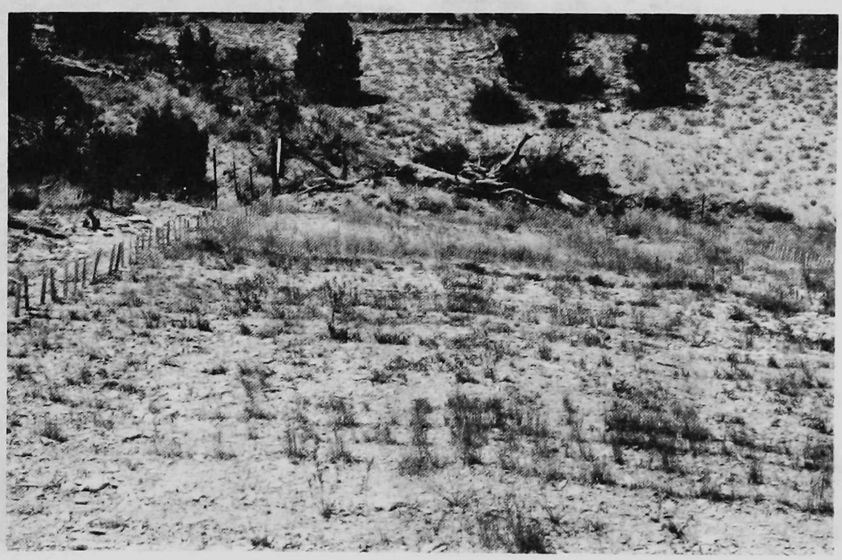


Figure 17. Low Elevation Pinyon-Juniper Location, 4 to 1 north facing slope.

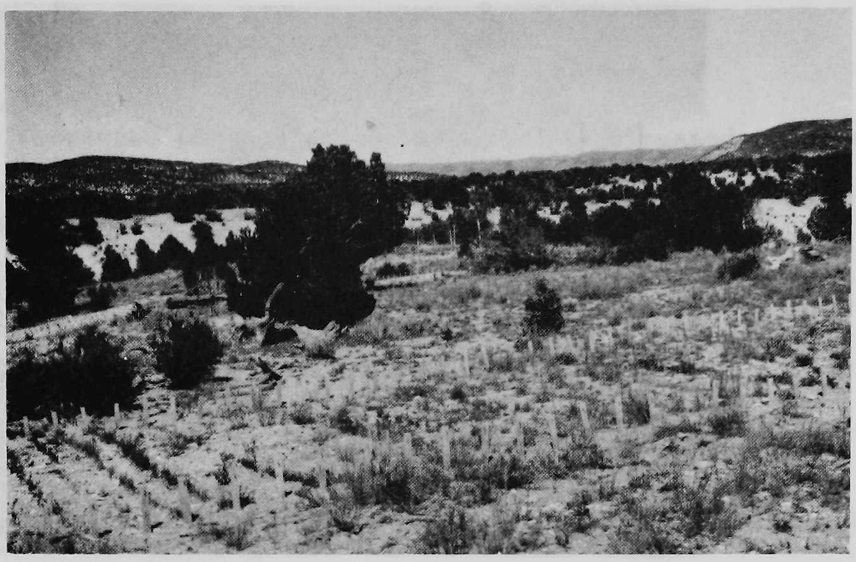


Figure 18. Low Elevation Pinyon-Juniper Location, ridge top.

Figure 19. Left to right: Durar hard fescue, Amur intermediate wheatgrass, Critana thickspike wheatgrass, and Oahe intermediate wheatgrass at Low Elevation Pinyon-Juniper Location.

fractured and weathered platy shale rock. The R horizon was a solid platy shale bedrock (Appendix, Table 4).

The canopy cover of the native vegetation on the south exposure was approximately 18 percent. The vegetation was dominated by Utah juniper, mountain mahogany, winterfat, western wheatgrass, Indian ricegrass, rock aster, small flower aster, phlox, and goldenweed. Utah juniper composed 3 percent of the canopy cover, mountain mahogany 2, winterfat 2, western wheatgrass 2, Indian ricegrass 2, rock aster 2, smallflower aster 1, phlox 1, and goldenweed 1 percent.

The native vegetation on the north exposure had a ground cover of 30 percent. The dominant species were pinyon pine, with 11 percent cover, serviceberry 3, mountain mahogany 2, western wheatgrass 2, rock aster 3, evening primrose 3, goldenweed 2, phlox 2, and white buckwheat 1 percent.

Finally the ridge top had approximately 28 percent canopy cover with the dominant species being pinyon pine, with 8 percent ground cover. Other important species were mountain mahogany 4 percent, winterfat 2, Utah juniper 1, western wheatgrass 1, Indian ricegrass 1, rock aster 6, goldenweed 1, and phlox 1 percent.

Species Evaluation

There were 54 species seeded at the low elevation pinyon-juniper location in October 1973. Of these 54 species, nine grasses, eight forbs and legumes, and three browse species displayed good to excellent emergence and survival during the second growing season. In 1973, eight grasses and three forbs showed good to excellent emergence during the first growing season (Table 2).

Table 2. Summary table for the adaptability of the best grasses, forbs and browse seeded on three different aspects at the low elevation pinyon-juniper location. Data collected in 1973 and 1974.

Species	1973 Data Adaptability on different aspects*			1974 Data Adaptability on different aspects**			Remarks
	North slope	Ridge top	South slope	North slope	Ridge top	South slope	
Grasses							
Nordan crested wheatgrass	4	4	2	3	4	2	bunchgrass, introduced, highly palatable and nutritious
Critana thickspike wheatgrass	3	4	2	4	3	2	sod-former, native, fair forage for livestock
Amur intermediate wheatgrass	4	4	3	4	4	3	sod-former, introduced, highly palatable
Oahe intermediate wheatgrass	4	4	3	4	4	3	sod-former, introduced, highly palatable
Sodar streambank wheatgrass	3	4	2	3	4	4	sod-former, native, unpalatable
Rosana western wheatgrass	3	3	2	3	3	3	sod-former, native, salt-tolerant, good forage
Luna pubescent wheatgrass	4	4	4	4	4	4	sod-former, introduced, very productive on severe sites
Regar meadow brome	4	4	4	4	4	4	bunchgrass, introduced
Green needlegrass	3	3	3	3	4	3	bunchgrass, native, good forage value
Forbs							
Penngift crownvetch	4	4	2	4	4	3	native, legume
Utah sweetvetch	4	4	4	4	4	4	native, legume, produces abundant forage
Lewis flax	2	1	1	4	4	2	native, grows on well drained soils
Rhizoma alfalfa	3	2	0	3	4	3	introduced, legume, rhizomatous
Rambler alfalfa	4	2	1	4	4	3	introduced, legume, rhizomatous
Madrid yellow sweetclover	4	4	3	3	3	3	rapid growing biennial, introduced
Small burnet	4	3	1	4	4	2	introduced, low growing, life expectency 7 to 12 years

Table 2 Continued.

Species	1973 Data Adaptability on different aspects* North slope	Ridge top	South slope	1974 Data Adaptability on different aspects** North slope	Ridge top	South slope	Remarks
Arrowleaf balsamroot	3	3	2	4	3	4	native, highly productive
Browse							
Yellowbrush	0	1	0	3	3	2	native, used lightly by livestock and big game
Winterfat	1	...	1	3	...	4	native, drought resistent, highly palatable
Green ephedra	3	3	2	4	4	2	native, evergreen, moderate to high palatability

* Emergence ratings: 0--none, 1--poor, 2--fair, 3--good, 4--excellent.

** Emergence and survival ratings: 0--none, 1--poor, 2--fair, 3--good, 4--excellent.

... not seeded on this aspect because of a lack of adequate space.

Grasses

Nordan crested wheatgrass performed well at this location. In 1973 it was rated excellent on the north exposure and the ridge top and had a fair emergence rating on the south exposure. Wheatgrass was significantly poorer ($P<.01$) on the south exposure than on the north exposure and on the south exposure compared to the ridge top. The treatments, on the other hand, showed no significant difference. Survival ratings were taken in 1974 and similar results were recorded again. Nordan crested wheatgrass had shown good survival on the north aspect, excellent survival on the ridge top, but only fair survival on the south exposure (Table 2).

Critana thickspike wheatgrass was very similar to Nordan crested wheatgrass in its emergence and survival (Figure 19). It had good emergence and survival on the north aspect and the ridge top, but only fair emergence and survival on the south slope (Table 2). Again there was a significant difference ($P<.05$) between sites in 1973, but not between treatments.

Amur intermediate wheatgrass had excellent emergence and survival (Table 2, Figure 19). As with the previous species it performed better on the two more favorable aspects than on the less favorable dryer south aspect. Although there was a difference, it was not statistically significant. Survival was excellent on the north aspect and on the ridge top. The south exposure had good but not excellent survival, and the treatments were similar on all sites.

Oahe intermediate wheatgrass has done slightly better than Amur intermediate wheatgrass in both emergence and survival (Figure 19).

The results for both species were very similar on all sites and both treatments (Table 2). Both species have shown a great deal of promise for future rehabilitation work in this vegetation type.

Sodar streambank wheatgrass demonstrated good emergence in 1973 and good to excellent emergence and survival in 1974. It did as well on the south aspect as it did on the two more favorable expressions in 1974. During the first growing season, however, it performed significantly better (P<.01) on the north aspect and ridge top than on the south aspect No significant difference was recorded between treatment.

Rosana western wheatgrass is a sod-forming perennial found throughout the western states. It is somewhat salt tolerant and is a good forage for livestock and big game animals. This variety indicated significantly better emergence (P<.01) on the north aspect and ridge top than on the south aspect in June 1973.

In 1974 there was consistent emergence and survival throughout the location (Table 2). Rosana western wheatgrass has shown good success with no measureable difference between plowing and scraping.

Luna pubescent wheatgrass was the best grass species at this location (Figure 20). It consistently had excellent ratings for emergence and survival (Table 2). It performed no differently on either treatment or on any of the three sites.

Regar meadow brome, like Luna pubescent wheatgrass, also demonstrated excellent emergence and survival throughout the low elevation pinyon-juniper location. No significant differences were recorded in 1973 between treatments or among sites.

Green needlegrass did not do as well as some of the introduced species, but it did maintain good emergence and survival in 1973

Figure 20. Left to right: Lewis flax and Luna pubescent wheatgrass at Low Elevation Pinyon-Juniper Location.

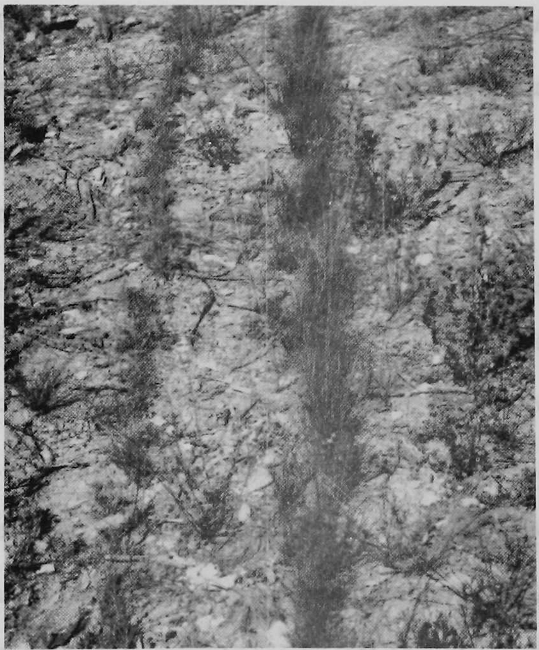


Figure 21. Left to right: Jose tall wheatgrass and Green needlegrass at Low Elevation Pinyon-Juniper Location.

and 1974 (Table 2, Figure 21). It had significantly better emergence ($P<.01$) and slightly better survival on the ridge top and north aspect than it did on the south aspect. Plowing and scraping showed some difference, but they were not significantly different.

Forbs

The forb and legume species did exceptionally well at the low elevation pinyon-juniper location. In 1973, three species had to excellent emergence. In 1974, eight species displayed good to excellent emergence and survival (Table 2).

Penngift crownvetch is a native legume found in many western stages (Figure 22). It showed good to excellent emergence and survival in 1973 and 1974. During emergence it showed a significant difference ($P<.05$) between sites, with the ridge top and north exposures displaying the best emergence. Plowing and scraping, however, were similar throughout the location. Emergence and survival in 1974 were a little more consistent, with the south exposure changing from fair to good (Table 2).

Utah sweetvetch was an excellent species at this location. Of all the forbs it performed the best. Emergence and survival in 1973 and 1974 were consistent throughout the plot with excellent ratings on all sites and treatments. Since Utah sweetvetch is a native plant to the pinyon-juniper areas in Utah, it should be a well adapted species for revegetation purposes at this location.

Lewis flax was one of the slower species to emerge during the first growing season (Figure 20). But in the second growing season

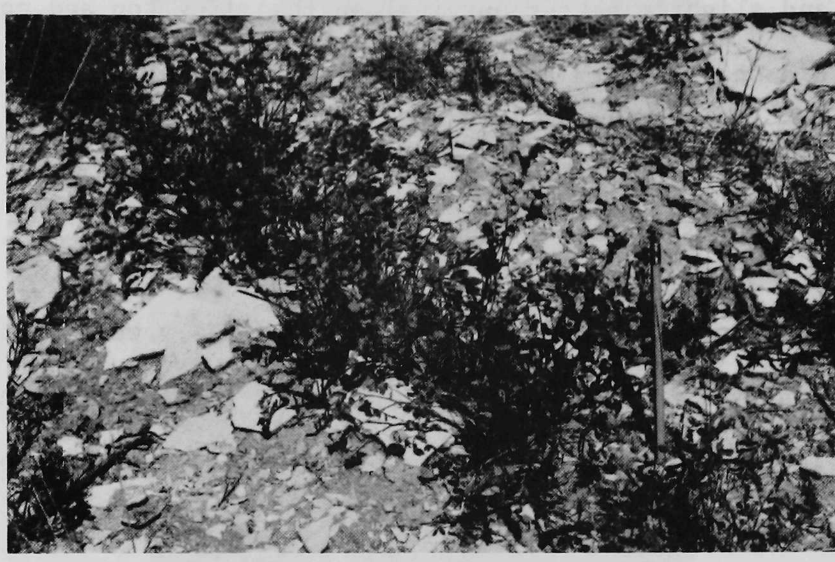


Figure 22. Penngift crownvetch at Low Elevation Pinyon-Juniper Location.

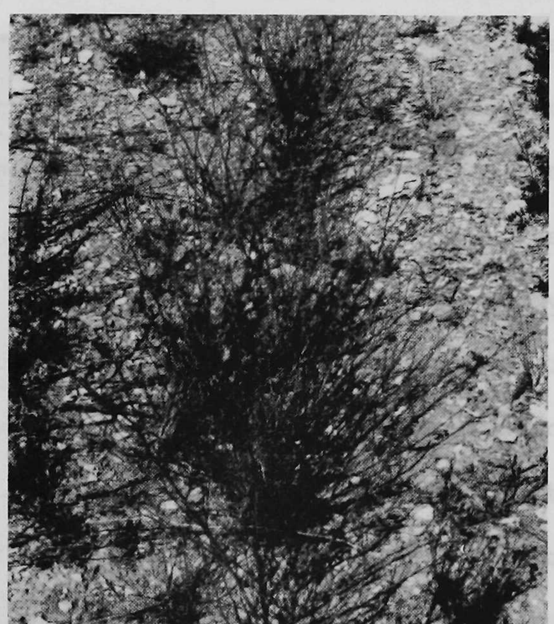


Figure 23. Madrid yellow sweetclover at Low Elevation Pinyon-Juniper Location.

it progressed quickly and demonstrated fair emergence and survival on the south exposure and good to excellent emergence and survival on the remaining sites (Table 2). There were differences in the treatments, but neither plowing or scraping was significantly better than the other in 1973.

Rhizoma alfalfa had fair emergence in 1973, but good to excellent emergence and survival in 1974 (Table 2). There was a significant difference ($P<.05$) between sites in 1973. In 1974 Rhizoma alfalfa showed slightly better emergence and survival on the plowed treatment and on the ridge top and north exposure, but the difference was very minimal.

Rambler alfalfa is an introduced legume very similar to Rhizoma. It produces a larger crown and an elaborate root system with underground stems. Rambler alfalfa had better initial emergence than Rhizoma, but both varieties displayed nearly identical results during the second growing season. During the first growing season there was a significant difference ($P<.05$) in sites but not between treatments.

Madrid yellow sweetclover emerged quickly during the first growing season and was rated good to excellent (Table 2, Figure 23). There was a significant difference ($P<.01$) between sites at this time, but not between treatments. During the second growing season it had good emergence and survival, with more consistency throughout the location. Madrid yellow sweetclover would be recommended here primarily for its quick growth which is needed for stabilizing highly erodable soils.

Small burnet is a low-growing forb introduced from Spain from sites similar to the Pinyon-Juniper vegetation types (Figure 24).

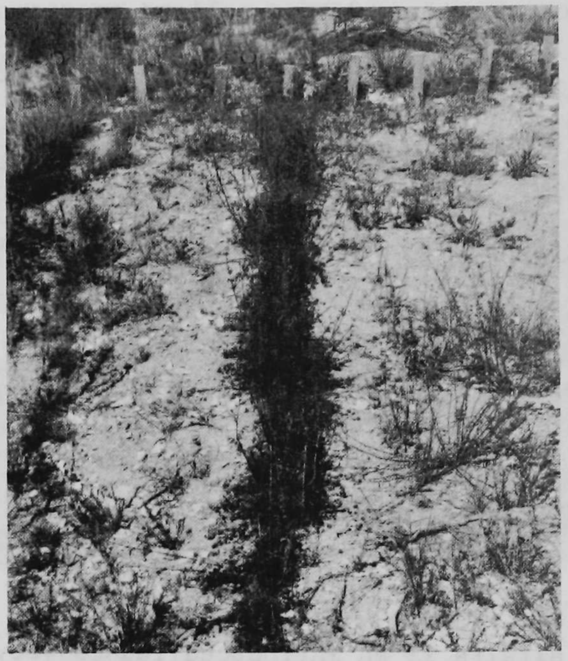


Figure 24. Small burnet at Low Elevation Pinyon-Juniper Location.

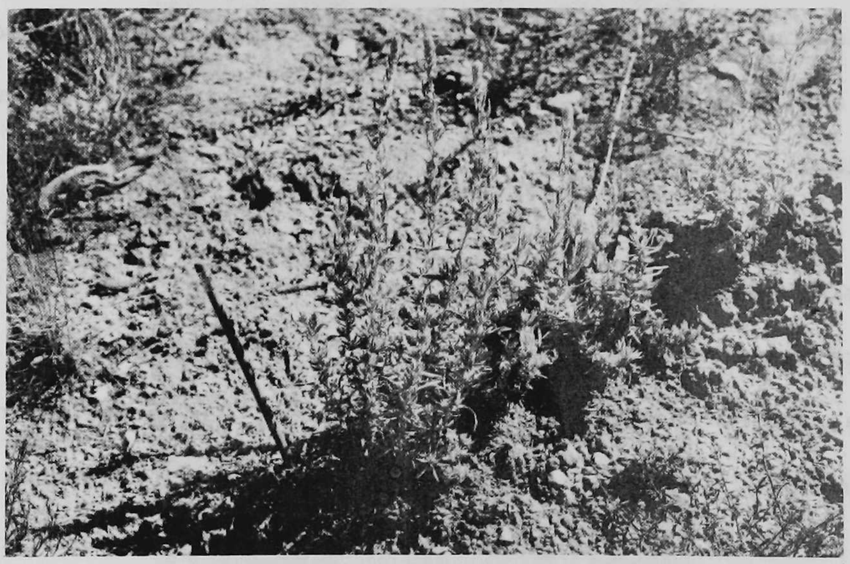


Figure 25. Winterfat at Low Elevation Pinyon-Juniper Location.

It becomes established quickly and has a life expectancy of seven to 12 years. Its seed is highly desired by rodents and the plant also provides good forage for game animals in late winter and early spring.

Small burnet was an exceptionally good species on the ridge top and north exposure during the first and second growing seasons (Table 2). But it had only poor to fair emergence and survival on the south exposure. Statistically it showed differences ($P<.05$) in sites in 1973, but no difference in treatments.

Arrowleaf balsamroot, a native forb, is found primarily in the High Elevation Pinyon-Juniper and Mountain Browse vegetation types throughout the Piceance Basin. Big game species are attracted to its succulent foliage in early spring and its seedheads in summer.

Arrowleaf balsamroot provided fair to good emergence during the first growing season, with the ridge top and north aspect showing the best emergence (Table 2). During the second growing season arrowleaf displayed good to excellent emergence and survival, with the south aspect dominating the ridge top (Table 2). Significant differences between treatments or among sites were not recorded.

Browse

On a whole the browse plants did not fair well at this location. Only three species showed good to excellent emergence and survival in 1974 (Table 2). Browse seed was slower to emerge due to dormancy, a lack of water near the soil surface, and a loss of seed to birds and rodents.

Yellowbrush had very poor emergence throughout the plot during the first growing season (Table 2). In 1974 it showed good emergence throughout the location with the south exposure being slightly surpassed by the other two aspects (Table 2). Statistically there were no differences between site or treatments.

Winterfat was seeded only on the north and south aspects due to a lack of adequate space on the ridge top (Figure 25). This species showed poor emergence during the first growing season (Table 2), but good to excellent emergence and survival during the second growing season. Winterfat is a highly preferred species by all large herbivores and will be an exceptionally good species for this location.

Green ephedra was the only other browse species which had good ratings at the low elevation pinyon-juniper location (Figure 26). It had fair to good emergence during the first growing season and fair to excellent emergence and survival during the second growing season (Table 2). The ridge top and north exposure exceeded the south exposure in emergence and survival in both years, but no significant difference was recorded between sites or treatments.

Selected Species

At the low elevation pinyon-juniper location the forb species excelled almost as well as the grasses did. The browse species have been much slower, but have performed well considering the soil texture, low soil water and steep slopes found at this location. The native browse species that had the best emergence and survival during the second growing season included yellowbrush, green ephedra

Figure 26. Green ephedra at Low Elevation Pinyon-Juniper Location.

and winterfat. Other native browse species such as true mountain mahogany, black sagebrush, big sagebrush, shadscale saltbush, and skunkbush sumac have just begun to emerge and may very well be promising species for future revegetation programs.

The native forb species which performed well during the second growing season were Penngift crownvetch, Utah sweetvetch, Lewis flax, and arrowleaf balsamroot. Native grasses which were found to be superior during this study period were Critana thickspike wheatgrass, Sodar streambank wheatgrass, Rosana western wheatgrass, and green needlegrass.

Of the 19 species described in the narrative, 12 of them are native to either the Piceance Basin or the western states. All 19 species are well adapted to this vegetation type and are highly recommended at this time for revegetation of surface disturbances in this vegetation type.

High Elevation Pinyon-Juniper Location

Description of Location

The high elevation pinyon-juniper location is located on the western boundary of the C-b federal lease site. At an elevation of 2,123 meters it is situated in the upper portions of the Pinyon-Juniper vegetation type.

In 1967 this area was chained by the Bureau of Land Management and was seeded to crested wheatgrass. The legal description of this location is: T. 3S., R. 97W., Sec. 13, NE¼, SE¼, NE¼.

The average annual precipitation for this area will vary from 35 cm to 45 cm. Approximately 44.8 cm were received during a 14 month period in 1972 and 1973 (Appendix, Table 5). Approximately 28 of these 44.8 cm were in form of snow.

The native vegetation was composed primarily of antelope bitterbrush, snowberry, big rabbitbrush, big sagebrush, mountain mahogany, broom snakeweed, goldenweed, false yarrow, scarlet globemallow, bladderpod, stickseed, mustard, lambsquarters, hawksbeard, western wheatgrass, Indian ricegrass, sheep fescue, foxtail barley, squirreltail, cheatgrass, and crested wheatgrass.

The high elevation pinyon-juniper location included two aspects in its experimental design. The first expression was a 4 to 1 south facing slope and the second exposure was a gentle sloping north to northwest aspect (Figures 27 and 28). The soil on the two expressions was similar, with the A-11 horizon being a noncalcareous light loam with a field determined pH of 8.4. The A-12 horizon was a weakly calcareous light loam with a pH of 8.6, while the C-2ca horizon was a very fine sandy loam also with a pH of 8.6. The CR horizon was a lime coated weathered and fractured sandstone and the residual layer was a somewhat fractured sandstone bedrock (Appendix, Table 4).

The northwest aspect had a native canopy cover of approximately 46 percent. Western wheatgrass was the most dominant species with a ground cover of 12 percent. Other important species were antelope bitterbrush 8, snowberry 3, big rabbitbrush 3, goldenweed 4, false yarrow 2, hawksbeard 1, scarlet globemallow 1, Indian ricegrass 4, sheep fescue 3, crested wheatgrass 1, and squirreltail 1 percent canopy cover.

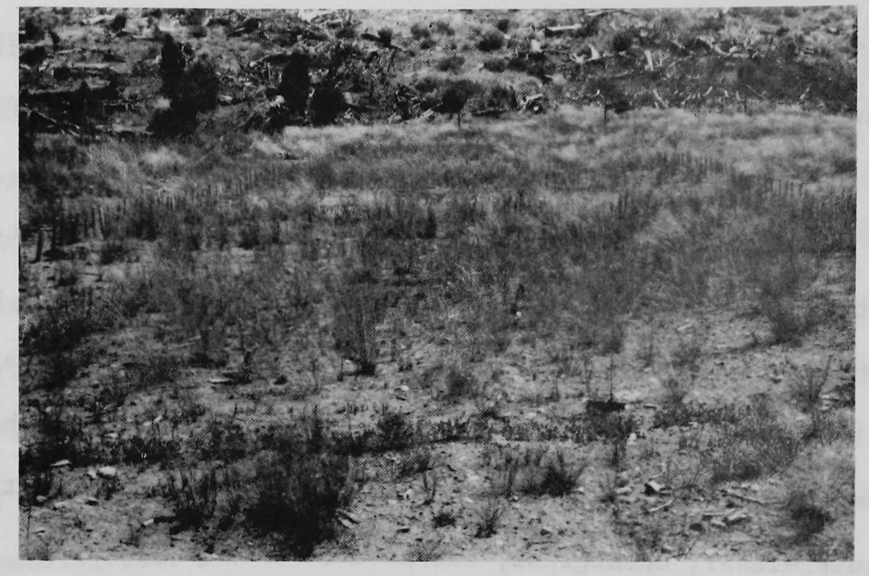


Figure 27. High Elevation Pinyon-Juniper Location, 4 to 1 south facing slope.

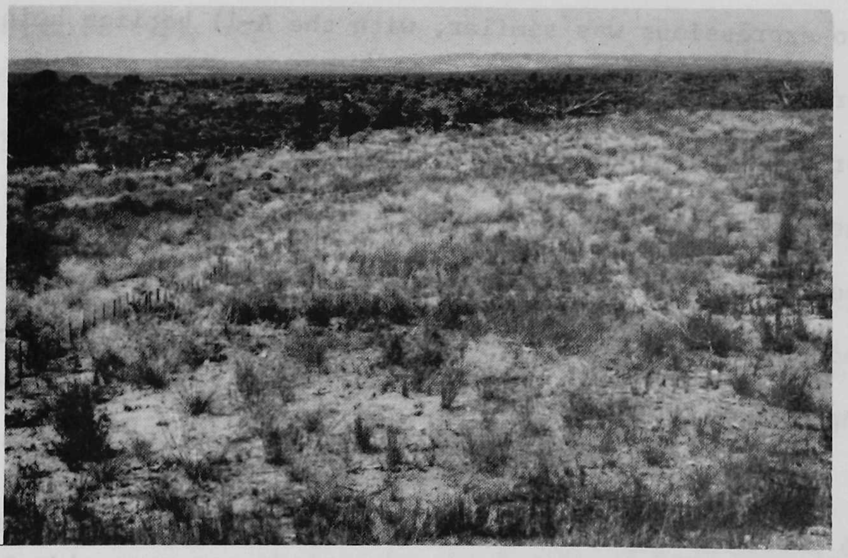


Figure 28. High Elevation Pinyon-Juniper Location, northwest aspect.

Turning to the south aspect, the natural canopy cover here was also 46 percent. The dominant species at this aspect were cheatgrass at 7 percent, foxtail barley 6, Indian ricegrass 5, western wheatgrass 5, squirreltail 1, sheep fescue 1, mustard 4, lambsquarters 3, bladderpod 2, stickseed 2, antelope bitterbrush 3, big sagebrush 3, and mountain mahogany 1 percent ground cover.

Species Evaluation

Of the 66 species seeded at the high elevation pinyon-juniper location, 25 were grasses, 19 were forbs and legumes, and 22 were browse. During the second growing season, 12 grasses, eight forbs, and four browse species showed good to excellent emergence and survival (Table 3).

Grasses

Nordan crested wheatgrass demonstrated good to excellent emergence and survival during the second growing season at this location (Table 3). In 1973 it performed better on the northwest aspect than on the south exposure, but there were no significant differences between sites or treatments. In 1974 it again performed better on the northwest aspect and plowing supported better emergence and survival on both aspects.

Critana thickspike wheatgrass had good emergence and survival at this location in 1974 (Table 3). It showed consistent ratings throughout the location in 1973 with no significant differences between sites or treatments.

Table 3, Summary table for the adaptability of the best grasses, forbs and browse seeded on two different aspects at the high elevation pinyon-juniper location. Data collected in 1973 and 1974.

Species	1973 Data Adaptability on different aspects*		1974 Data Adaptability on different aspects**		Remarks
	Northwest slope	South slope	Northwest slope	South slope	
Grasses					
Nordan crested wheatgrass	4	2	4	3	bunchgrass, introduced, highly palatable and nutrious
Critana thickspike wheatgrass	2	2	3	3	sod-former, native, fair forage for livestock
Jose tall wheatgrass	3	2	4	3	bunchgrass, introduced, salt-tolerant
Amur intermediate wheatgrass	4	4	4	4	sod-former, introduced, highly palatable
Oahe intermediate wheatgrass	4	4	4	4	sod-former, introduced, highly palatable
Siberian wheatgrase	3	2	3	3	bunchgrass, intoduced
Rosana western wheatgrass	3	2	4	2	sod-former, native, salt-tolerant, good forage
Luna pubescent wheatgrass	4	4	4	4	sod-former, introduced, very productive on severe sites
Mountain brome	3	2	4	3	bunchgrass, native, short-lived perennial
Regar meadow brome	4	4	4	4	bunchgrass, introduced
Manchar brome	2	2	3	3	sod-former, introduced, highly palatable
Green needlegrass	4	4	4	4	bunchgrass, native, good forage value
Forbs					
Penngift crownvetch	4	4	2	2	native, legume
Madrid yellow sweetclover	4	4	2	2	rapid growing biennial, introduced
Sweetanise	3	4	2	2	native, highly palatable, important range plant
Utah sweetvetch	4	4	3	4	native, legume, produces abundant forage
Rhizoma alfalfa	2	1	3	3	introduced, legume rhizomatous

Table 3 Continued.

Species	1973 Data Adaptability on different aspects*		1974 Data Adaptability on different aspects**		Remarks
	Northwest slope	South slope	Northwest slope	South slope	
Palmer penstemon	3	4	4	4	native, short-lived perennial, grows well on disturbed sites
Rocky Mountain penstemon	4	4	4	4	native, good forage
Bouncing-bet	4	4	3	3	introduced, rhizomatous
Gooseberry-leaf globemallow	1	2	3	4	low growing native, rhizomatous
Verbena	1	2	4	3	native, bright showy purple flowers
Arrowleaf balsamroot	4	4	4	4	native, highly productive
<u>Browse</u>					
Common bladdersenna	3	4	2	2	native, quick growing, unpalatable
Green ephedra	4	4	2	3	native, evergreen, noderate to high palatability
Desert bitterbrush	3	3	3	2	native, evergreen highly palatable
Yellowbrush	2	2	3	3	native, used lightly by livestock and big game
Stansbury cliffrose	3	3	2	4	native, broad-leaved evergreen, grows well on severe sites
Black chokecherry	2	3	3	3	native, highly preferred species by big game and game birds
Antelope bitterbrush	3	4	4	4	native, highly palatable

* Emergence ratings: 0--none, 1--poor, 2--fair, 3--good, 4--excellent.

** Emergence and survival ratings: 0--none, 1--poor, 2--fair, 3--good, 4--excellent.

Jose tall wheatgrass, during the first growing season had fair to good emergence (Table 3, Figure 29). At this time it also had significantly better emergence ($P<.05$) on the northwest aspect than on the south aspect. During the second growing season, the emergence and survival of Jose tall wheatgrass was good (Table 3). Again the northwest exposure was slightly better. Plowing and scraping were similar throughout the location.

Amur and Oahe intermediate wheatgrass both showed excellent emergence in 1973 and excellent survival in 1974 (Table 3). Both species faired equally well on both sites and on both treatments (Figures 30 and 31).

Siberian wheatgrass demonstrated good emergence and survival during the second growing season (Table 3). It had only fair emergence during the first growing season, and performed slightly better on the northwest aspect (Table 3). There were no significant differences between sites or treatments during the first growing season.

Rosana western wheatgrass performed better on the northwest exposure during the first and second growing seasons (Table 3). It displayed good emergence and survival in 1974 and fair to good emergence in 1973. Statistically significant differences between treatments and sites were not recorded in 1973.

Luna pubescent wheatgrass showed excellent emergence in 1973 (Table 3, Figure 32). It also performed well in 1974 (Table 3). Luna pubescent wheatgrass displayed consistent emergence and survival

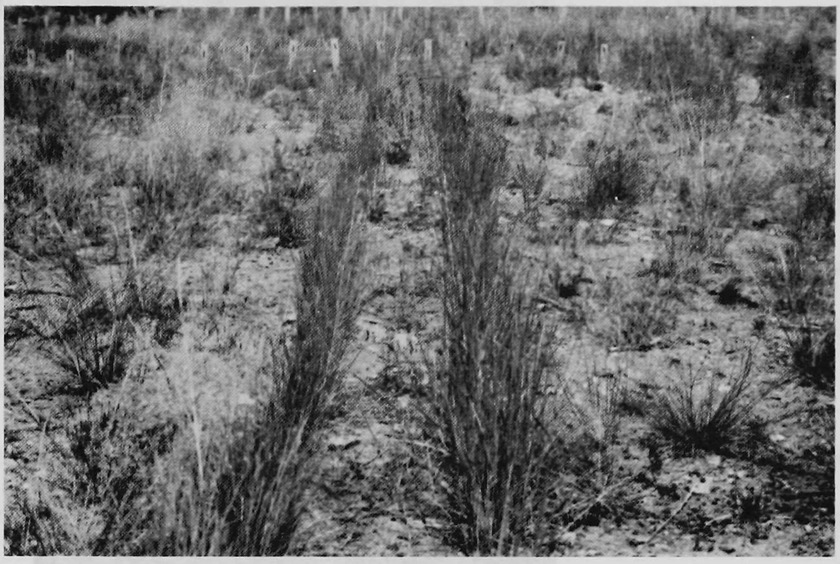


Figure 29. Left to right: Green needlegrass and Jose tall wheatgrass at High Elevation Pinyon-Juniper Location.

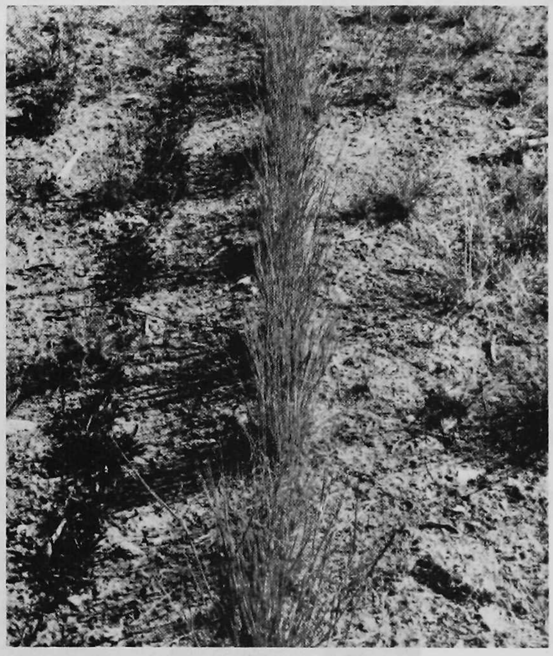


Figure 30. Left to right: Rocky Mountain penstemon and Amur intermediate wheatgrass at High Elevation Pinyon-Juniper Location.

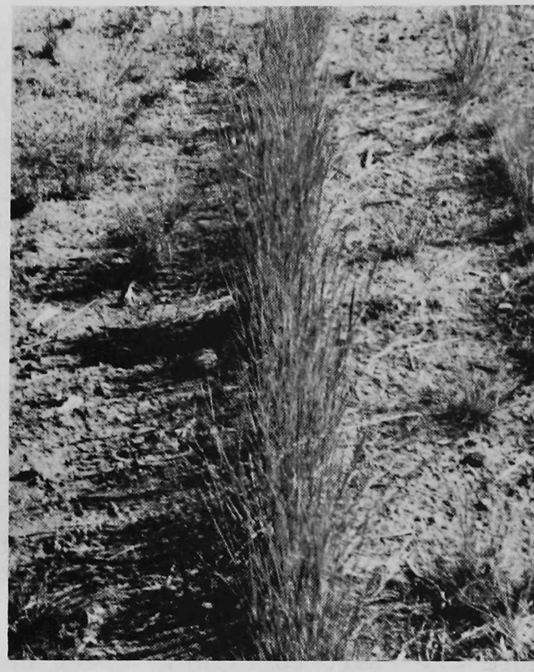


Figure 31. Oahe intermediate wheatgrass at High Elevation Pinyon-Juniper Location.

Figure 32. Luna pubescent wheatgrass at High Elevation Pinyon-Juniper Location.

on all sites and all treatments throughout this location and has been a highly recommended species for revegetation work.

Mountain brome was another species which displayed fair to good emergence during the first growing season and good to excellent emergence and survival during the second growing season (Table 3). It performed better on the northwest exposure during both seasons, but statistically the differences were not significant between sites or treatments.

Regar meadow brome displayed consistent emergence in 1973 and consistent emergence and survival in 1974. It was rated excellent in both years on both sites and both treatments (Table 3).

Manchar brome was introduced in 1935 from Manchuria. It is a rhizomatous species which is highly palatable. Manchar brome has been used extensively in revegetation programs, especially in subalpine areas (Berg 1974; Quany 1974). In this research, Manchar brome showed only fair emergence in 1973, but good emergence and survival in 1974 (Table 3). Its performance was very similar on both exposures and treatments, therefore no significant differences were noted during the first growing season.

Green needlegrass was an outstanding species at this location (Figure 29). It had an excellent rating on each site and on each treatment during both growing seasons (Table 3). It has been a well adapted species at this vegetation zone.

Forbs

The forb and legume species also did well at the high elevation pinyon-juniper location. During 1973 there were eight species that had good to excellent emergence. In 1974 there were again eight species that were rated good to excellent (Table 3). Some species continued from the first growing season with outstanding survival, while others had lower levels of survival.

Penngift crownvetch showed excellent emergence during the first growing season, but displayed only fair survival during the second growing season (Table 3). Because of the very dry conditions which persisted during the spring and summer of 1974, survival of this species was lowered. Statistically there were no differences between treatments or among sites.

Madrid yellow sweetclover displayed exceptional emergence during the first growing season as did Penngift crownvetch (Table 3). Emergence was consistent on all sites and all treatments throughout the location. But due to the dryer conditions which existed, Madrid yellow sweetclover was able to show only fair survival during the second growing season (Table 3).

Sweetanise is by far one of the most important range plants in the sweetroot (Osmorhiza) genus. It is a native perennial which can be found at elevations up to 3,050 meters. It is highly palatable to all classes of livestock plus deer and elk. Unfortunately, sweetanise becomes dry and worthless after the first heavy frost (U.S. Forest Service 1937).

This species showed outstanding emergence in 1973, but displayed only fair survival in 1974 (Table 3). It did slightly better on the south aspect in 1973, but no significant differences were recorded. Further data will be necessary before this species can be recommended for revegetation purposes.

Utah sweetvetch was an exceptional legume at this location. It displayed excellent emergence and survival in 1973 and 1974 (Table 3). It performed equally well on both sites and on both treatments and appeared to be well adapted to this vegetation type.

Rhizoma alfalfa had poor emergence in 1973, but displayed good emergence and survival in 1974 (Table 3). Emergence was consistent throughout the location with no significant differences between sites or treatments.

Palmer penstemon is a short-lived perennial native forb at elevations above 2,135 meters (Figure 33). This species does well on disturbed areas and is sought after by big game species because of its green forage throughout the winter.

Palmer penstemon performed well at this location. It had good to excellent emergence in 1973 and excellent emergence and survival in 1974 (Table 3). It did slightly better on the south exposure, but statistically there were no differences between sites or treatments in 1973.

Rocky Mountain penstemon had better emergence and survival than Palmer penstemon (Figure 30). This species had excellent emergence during the first growing season and excellent emergence and survival during the second growing season (Table 3). It performed equally well throughout the location without any significant differences.

Bouncing-bet displayed excellent emergence during the first growing season (Table 3). It was rated good during the second growing season, showing consistent emergence and survival throughout the location. Statistically, no significant differences were recorded during the first year of growth.

Figure 33. Palmer penstemon at High Elevation Pinyon-Juniper Location.

Figure 34. Verbena at High Elevation Pinyon-Juniper Location.

Gooseberry-leaf globemallow is a species of globemallow very similar to the native, scarlet globemallow. Gooseberry-leaf is a rhizomatous low growing forb which has great potential for stabilizing eroding soils. It also has bright orange blossoms that would be useful for aesthetic purposes.

Gooseberry-leaf globemallow was very slow to emerge during the first growing season (Table 3). It developed quickly during the second growing season and showed good to excellent emergence and survival (Table 3). Statistically, it performed the same on both sites and both treatments in 1973.

Verbena is a native perennial with bright showy purple flowers (Figure 34). It is a low growing forb that would also be useful for stabilizing eroding soils and beautifying certain areas such as roadsides. Verbena had poor to fair emergence in 1973, but good to excellent emergence and survival in 1974 (Table 3). Statistically no significant differences were recorded during the first growing season. It has grown well at this location and would be considered a very promising species.

Arrowleaf balsamroot displayed excellent emergence in 1973 and excellent survival in 1974. Statistically it performed the same on the plowing and scraping on both the south aspect and the northwest aspect during emergence.

Browse

Browse species were slower to emerge at this location as they were at the two previous locations. In 1973 five species were rated good to excellent. Of these five species, two species continued into 1974 with good to excellent survival. Two other species were also added to this list during the second growing season (Table 3).

Common bladdersenna is a native browse species which grows quickly and is easy to establish. This species is low in palatability, but would be an important shrub for soil stabilization. Common bladdersenna showed good to excellent emergence in 1973, performing significantly better ($P<.05$) on the south aspect than on the northwest aspect. In 1974, it displayed ~~fair~~ survival, with plowing being the better treatment on the northwest exposure and scraping being the better treatment on the south exposure.

Green ephedra had outstanding emergence during the first growing season. It performed equally well throughout the location (Table 3). In 1974 it displayed only fair to good survival with the plowing being better than the scraping on the northwest aspect and the south exposure being slightly better than the northwest exposure (Table 3).

Desert bitterbrush is a winter evergreen very similar to Stansbury cliffrose. It grows primarily in the Pinyon-Juniper vegetation types and is highly preferred by all kinds of grazing animals (Plummer 1968).

Desert bitterbrush had good emergence during the first growing season, but displayed only fair to good survival during the second growing season (Table 3). It performed slightly better on the northwest exposure during the second growing season. Plowing and scraping supported similar stands on both sites.

Yellowbrush was slow to emerge during the first part of 1973 (Table 3). By June 1974 it had displayed good emergence and survival throughout the location. It performed somewhat better on the south aspect during the second season of growth. Statistically it performed the same on the plowing and scraping on both the south aspect and the northwest aspect during emergence.

Stansbury cliffrose displayed good emergence during the first growing season, with the plowed treatment on the northwest exposure being significantly better ($P<.05$) than the scraped.

During the second growing season survival was good, with the south exposure being slightly better than the northwest exposure (Table 3).

Black chokecherry is a native shrub found primarily in the High Elevation Pinyon-Juniper and Mountain Browse vegetation types in the basin. It has the ability to resprout from roots which has been useful in erosion control. Black chokecherry is preferred by big game animals and game birds.

Black chokecherry displayed fair to good emergence in 1973, with the south exposure doing better than the northwest exposure (Table 3). Emergence and survival in 1974 were good with the treatments and sites displaying similar results (Table 3).

Antelope bitterbrush displayed good to excellent emergence in 1973 with the south exposure performing slightly better than the northwest aspect (Table 3). The treatments, however, were similar on both sites. In 1974 this species showed excellent survival throughout the location (Table 3). It is a well adapted species for the High Elevation Pinyon-Juniper vegetation type and should do well in rehabilitation programs.

Other browse species such as true mountain mahogany, Russian olive, green ephedra and winterfat would also have been promising species at this location in 1974. However, during the spring of 1974 these species were browsed heavily by mule deer. If it were not for the browsing, these species would have also had good to excellent ratings during the second year.

Selected Species

Preliminary results indicate that the 24 species discussed above, which demonstrated good to excellent emergence and survival during the second growing season, would be the species recommended for rehabilitation in this vegetation type. Of course, further information needs to be collected in subsequent years to determine if these species will continue to survive and if other species should show improvement.

The native species which displayed the best emergence and survival during the second growing season included Critana thickspike wheatgrass, Rosana western wheatgrass, Mountain brome, green needle-grass, Utah sweetvetch, Palmer penstemon, Rocky Mountain penstemon, Gooseberry-leaf globemallow, verbena, arrowleaf balsamroot, yellow-brush, Stansbury cliffrose, black chokecherry, and antelope bitter-brush. A seeding mixture of these native species would be recommended in order to establish a diverse self supporting plant community which would reduce soil erosion and provide habitats for domestic and wild herbivores.

Mountain Browse Location

Description of Location

The mountain browse location is located north of the C-b federal lease site between Stewart and Scandard gulches. Being situated at approximately 2,440 meters, this vegetation zones lies just above the High Elevation Pinyon-Juniper Woodland and just below the Aspen and Douglas Fir vegetation types. The legal description of this location is: T. 4S., R. 97W., Sec. 14, NE¼, NE¼, NW¼.

During the period of October 23, 1972 until September 19, 1973 the mountain browse location received approximately 44.8 cm of precipitation (Appendix, Table 4). The average annual precipitation for this area is between 45 cm and 55 cm. If 5 cm of precipitation were received in October 1973, then the annual total would have been approximately 50 cm.

The natural vegetation on the mountain browse location is dominated by serviceberry, big sagebrush, snowberry and antelope bitterbrush. Other less dominant species include western wheatgrass, Junegrass, sheep fescue, mountain brome, lupine, sulphur wildbuckwheat, hawksbeard, wild pea, arrowleaf balsamroot, phlox, evening primrose, Rocky Mountain penstemon, Indian paintbrush, loco, Douglas rabbitbrush, snakeweed, and horsebrush.

Within the mountain browse location there were two different exposures. The first exposure was a gentle sloping northwest aspect which gradually transformed into a 4 to 1 northwest aspect, creating the second exposure (Figures 35 and 36). The soil on both aspects was similar, but the vegetation was strikingly different due primarily to slope.

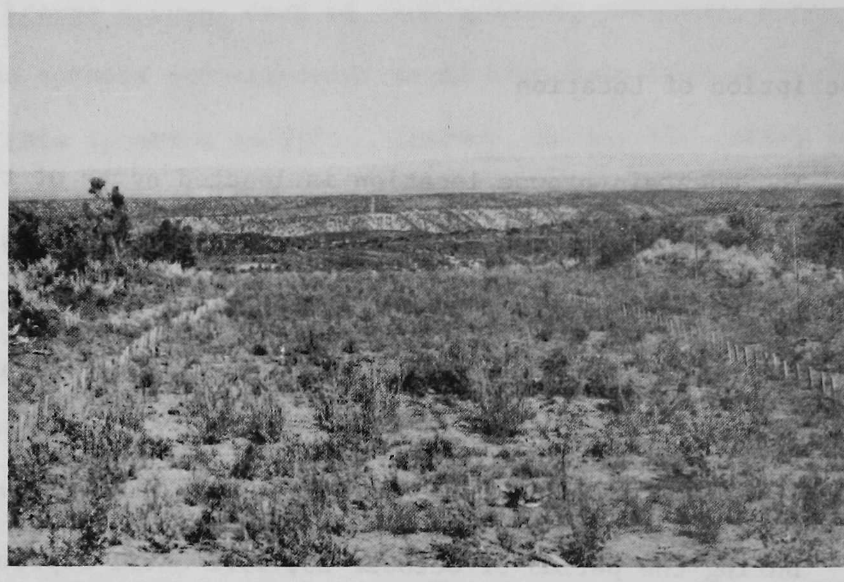


Figure 35. Mountain Browse Location, gentle northwest aspect.

Figure 36. Mountain Browse Location, steeper northwest aspect.

The A-11 horizon was composed of a very fine sandy loam with almost a neutral pH of 7.2. The A-12 horizon was a loam with a field determined pH again of 7.2. The CR horizon was a channery loam with a pH of 7.4, while the residual layer was composed of sandstone with a pH of 7.6 (Appendix, Table 4).

The native vegetation on the gentle sloping aspect had a canopy cover of approximately 76 percent. The most dominant plant species on this aspect was serviceberry with a canopy cover of 20 percent. Other browse species of major importance were big sagebrush with 14 percent ground cover, snowberry 8, antelope bitterbrush 7 and snakeweed at 3 percent canopy cover. The forbs which were most abundant were sulphur wildbuckwheat with 7 percent cover, lupine 7, phlox 4, wild pea 2, Indian paintbrush 1, and arrowleaf balsamroot at 1 percent cover. The grasses on this aspect were very scarce with mountain brome representing about 1 percent canopy cover and sheep fescue, western wheatgrass and Junegrass less than 1 percent ground cover.

On the more steeper northwest aspect the average canopy cover was approximately 60 percent. The dominant species on this exposure was big sagebrush, with an 18 percent cover. Antelope bitterbrush had a 10 percent ground cover, snowberry 8, Douglas rabbitbrush 3, horsebrush 2, snakeweed 1, and serviceberry had less than 1 percent canopy cover. Serviceberry was the dominant species on the first aspect, but virtually disappeared on this aspect. This could be caused by chemical content of the soil or possibly the interaction of slope and other physical features of the soil. The dominant forbs included arrowleaf balsamroot 4, phlox 3, evening primrose 3, sulphur wildbuckwheat 2, lupine 2, scarlet globemallow 1, Rocky Mountain penstemon 1, and loco 1 percent ground cover. Finally, the grasses were again scarce with sheep fescue representing 2 percent canopy cover, western wheatgrass 1, and Junegrass and mountain brome less than 1 percent cover.

Species Evaluation

The same 66 species that were seeded at the high elevation pinyon-juniper location were also seeded at the mountain browse location. This location had the shortest growing season, but received the greatest amount of precipitation and had the best developed soil of all four locations. Therefore, it supported a better natural vegetation cover and was a more favorable environment to carry out revegetation studies. During the fall of 1972, 25 grasses were seeded, and of these 25, 13 demonstrated good to excellent emergence in 1973 and 15 displayed good to excellent emergence and survival in 1974 (Table 4). There were also 19 forbs and legumes seeded, in which eight showed good to excellent emergence during the first growing season and ten were rated good to excellent during the second growing season (Table 4). Finally, although there were 22 browse plants seeded at this location in 1972, only six had good to excellent emergence in 1973 and four demonstrated good to excellent emergence and survival in 1974 (Table 4).

Grasses

Nordan crested wheatgrass showed excellent emergence during the first growing season and good to excellent survival during the

Table 4. Summary table for the adaptability of the best grasses, forbs and browse seeded on two different aspects at the mountain browse location. Data collected in 1973 and 1974.

Species	Adaptability on different aspects*		Adaptability on different aspects**		Remarks
	Gentle north west slope	Steeper north west slope	Gentle north west slope	Steeper north west slope	
Grasses					
Nordan crested wheatgrass	4	4	3	4	bunchgrass, introduced, highly palatable and nutritious
Critana thickspike wheatgrass	4	4	4	4	sod-former, native, fair forage for livestock
Jose tall wheatgrass	4	4	4	4	bunchgrass, introduced, salt-tolerant
Amur intermediate wheatgrass	4	4	4	4	sod-former, introduced highly palatable
Oahe intermediate wheatgrass	4	4	3	4	sod-former, introduced highly palatable
Sodar streambank wheatgrass	4	4	4	4	sod-former, native, unpalatable
Siberian wheatgrass	4	4	4	4	bunchgrass, introduced
Rosana western wheatgrass	4	4	4	4	sod-former, native, salt-tolerant, good forage
Barton western wheatgrass	3	3	4	4	sod-former, native, salt-tolerant, good forage
Luna pubescent wheatgrass	4	4	4	4	sod-former, introduced, very productive on severe sites
Mountain brome	4	4	4	4	bunchgrass, native, short-lived perennial
Regar meadow brome	4	4	4	4	bunchgrass, introduced
Manchar brome	4	4	4	4	sod-former, introduced, highly palatable
C-43 basin wildrye	3	2	4	3	bunchgrass, native, tall robust, good cover and forage
Green needlegrass	4	4	4	4	bunchgrass, native, good forage value

Table 4. Continued.

Species	1973 Data Adaptability on different aspects*		1974 Data Adaptability on different aspects**		Remarks
	Gentle north west slope	Steeper north west slope	Gentle north west slope	Steeper north west slope	
Forbs					
Penngift crownvetch	4	4	3	4	native, legume
Utah sweetvetch	4	4	3	4	native, legume, produces abundant forage
Lewis flax	2	1	3	3	native, grows on well drained soils
Rambler alfalfa	3	2	4	3	introduced, legume, rhizomatous
Rhizoma alfalfa	3	4	4	4	introduced, legume, rhizomatous
Madrid yellow sweetclover	4	4	3	4	rapid growing biennial, introduced
Sweetanise	4	4	4	3	native, highly palatable, important range plant
Rocky Mountain penstemon	3	4	3	4	native, good forage
Bouncing-bet	4	4	2	4	introduced, rhizomatous
Arrowleaf balsamroot	4	4	4	4	native, highly palatable
Browse					
Common bladdersenna	4	3	2	2	native, quick growing, unpalatable
Desert bitterbrush	3	4	2	2	native, evergreen, highly palatable
Stansbury cliffrose	4	4	3	4	native, broad-leaved evergreen, grows well on severe sites
Green ephedra	4	4	3	4	native, evergreen, moderate to high palatability
Black chokecherry	4	4	4	4	native, highly preferred species by big game and game birds
Antelope bitterbrush	4	4	4	4	native, highly palatable

* Emergence ratings: 0--none, 1--poor, 2--fair, 3--good, 4--excellent.

** Emergence and survival ratings: 0--none, 1--poor, 2--fair, 3--good, 4--excellent.

second growing season (Table 4, Figure 37). During the second growing season, Nordan crested wheatgrass performed better on the 4 to 1 slope than on the more gentle sloping aspect. Statistically there were no significant differences during emergence in 1973.

Critana thickspike wheatgrass displayed excellent emergence in 1973 and excellent survival in 1974 (Table 4). It performed equally well throughout the location without any significant differences during the first growing season.

Jose tall wheatgrass was another species which had excellent emergence during the first growing season. Again, there were no significant differences between treatments or sites. Emergence and survival during the second year were also excellent (Table 4).

Amur and Oahe intermediate wheatgrass had excellent emergence on all sites and all treatments in 1973 (Table 4, Figures 38 and 39). Both species also had good to excellent survival during the second growing season, with Amur showing slightly better survival than Oahe (Table 4).

Sodar streambank wheatgrass showed excellent emergence in 1973 and excellent survival in 1974 (Table 4, Figure 39). Emergence and survival were consistent across treatments and sites. No significant differences were recorded during emergence.

Siberian wheatgrass displayed excellent emergence during the first growing season and excellent survival during the second growing season (Table 4, Figure 40). It performed equally well throughout the location showing no difference between sites or treatments.

Rosana western wheatgrass was also an excellent species at this location (Table 4). It emerged early and showed excellent

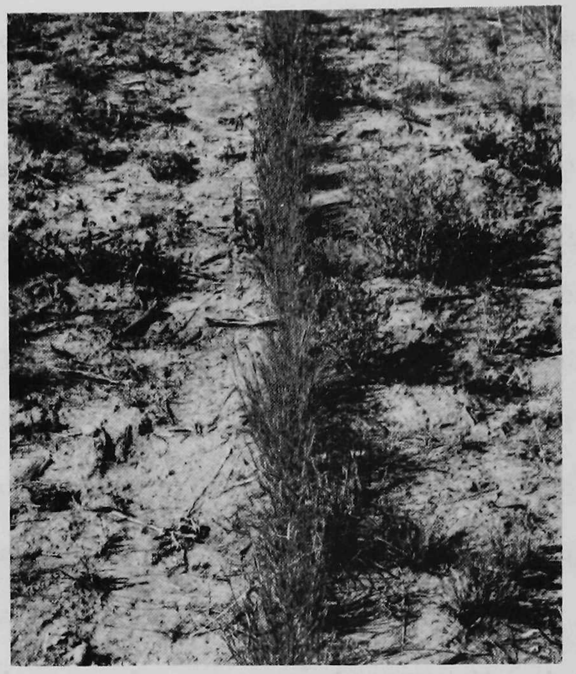


Figure 37. Nordan crested wheatgrass at Mountain Browse Location.

Figure 38. Amur intermediate wheatgrass at Mountain Browse Location.

Figure 39. Left to right: Oahe intermediate wheatgrass and Sodar streambank wheatgrass at Mountain Browse Location.

Figure 40. Left to right: Siberian wheatgrass, Luna pubescent wheatgrass, Indian ricegrass, and Mountain brome at Mountain Browse Location.

survival in the second growing season across both sites and treatments.

Barton western wheatgrass has been rated consistently lower than Rosana western wheatgrass at each location (Figure 41). It displayed good emergence in 1973 and excellent emergence and survival in 1974 on both sites and both treatments (Table 4). Although it had a high rating in 1974, it was still somewhat lower than Rosana. This is due primarily to the ten percent lower germination rate that Barton western wheatgrass had compared to Rosana western wheatgrass (Appendix, Table 3).

Luna pubescent wheatgrass was an outstanding species at this location (Figure 40). It had excellent emergence and survival through two growing seasons, displaying rapid growth and high vigor at all times (Table 4). It performed the same on both the plowing and scraping and on each site.

Mountain brome was another outstanding species which displayed excellent emergence and survival during two growing seasons (Table 4, Figure 40). Statistically mountain brome performed the same across treatments and sites. Being a native species to this vegetation type it should be an exceptionally good species for future revegetation projects in this vegetation zone.

Regar meadow brome had excellent emergence during the first growing season (Table 4). It also had excellent survival during the second year of growth (Figure 42). It performed equally well throughout the location and has been a well adapted species for this location.

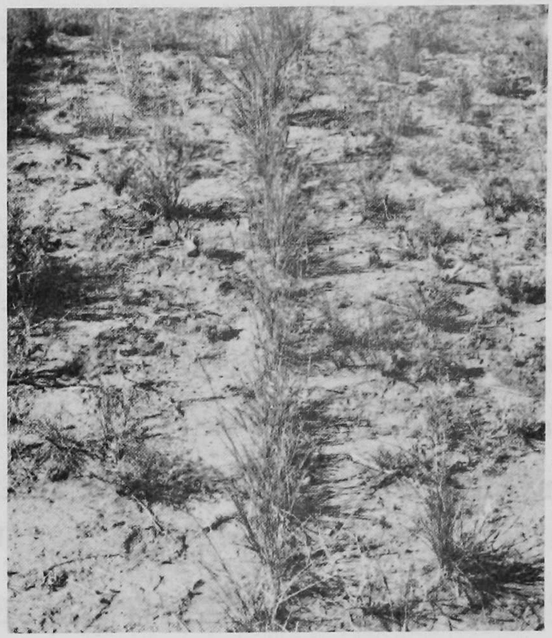


Figure 41. Barton western wheatgrass at Mountain Browse Location.

Figure 42. Left to right: Manchar brome, Madrid yellow sweetclover, Regar meadow brome, and Winterfat at Mountain Browse Location.

Manchar brome was also an excellent species, but was not as consistent as other grasses mentioned above (Figure 42). It was rated excellent in 1973 and 1974, with little difference between sites and treatments (Table 4).

C-43 basin wildrye was the grass in which the Ute Indians names the Piceance Basin after. The word Piceance, which means land of the tall grass, was representative of the condition in which the area existed before white man settled there.

C-43 basin wildrye is a tall robust bunchgrass that is salt tolerant. Because of its tall, heavy growth, this grass is especially useful as cover for upland game birds and forage for big game animals. It had fair to good emergence during the first growing season with the gentle northwest slope performing better than the steeper 4 to 1 aspect (Table 4). During the second growing season it displayed good to excellent emergence and survival, again with the gentler sloping site providing better results (Table 4). No significant differences were recorded between sites or treatments during emergence.

Green needlegrass showed excellent emergence during the first growing season and excellent survival during the second growing season (Table 4). No significant differences were found between sites or treatments in the first year.

Forbs

The forbs and legumes did very well at this location. In 1973, eight species demonstrated good to excellent emergence

(Table 4). During the second growing season ten species displayed similar results.

Penngift crownvetch was a well adapted legume at this location. It displayed excellent emergence in 1973 and good to excellent survival during the second growing season (Table 4). Statistically it had similar results throughout the location in 1973.

Utah sweetvetch demonstrated excellent emergence during the first growing season and good to excellent survival during the second growing season (Table 4). This species is well adapted to this location and will be an important species in revegetation programs. Statistically Utah sweetvetch had similar results throughout the location during the first growing season.

Lewis flax was a slow species to emerge and showed only poor to fair emergence in 1973 (Table 4). Good emergence and survival were recorded during the second growing season throughout the location (Table 4). Because of the large number of seeds produced yearly, this species should spread well naturally.

Rambler alfalfa demonstrated significantly better emergence ($P<.05$) on the gentle sloping northwest aspect than on the 4 to 1 slope during the first growing season. Emergence during the first growing season was fair to good and emergence and survival during the second growing season were good to excellent (Table 4). No difference between treatments was recorded.

Rhizoma alfalfa performed slightly better at this location than Rambler alfalfa. Good to excellent emergence ratings were recorded during 1973 and excellent emergence and survival ratings were recorded during 1974 (Table 4). Ratings were similar on both sites and both treatments.

Madrid yellow sweetclover grew rapidly during the first season of growth and showed good to excellent survival during the second season (Table 4, Figure 42). Although it is only a biennial, it volunteers well and should be suited in stabilizing severe sites because of its rapid growth. No differences were recorded between sites or treatments.

Sweetanise had excellent emergence in 1973, but was significantly better ($P<.05$) on the scraped gentle sloping site than on the scraped 4 to 1 aspect. Survival in 1974 was good to excellent, again with the gentle sloping site providing better ratings (Table 4). No difference between treatments was recorded.

Rocky Mountain penstemon was a native species that did well at this location. It had good to excellent emergence during the first growing season and good to excellent emergence and survival during the second season of growth on both sites and in both treatments (Table 4). Rocky Mountain penstemon is well adapted to this vegetation type and should be a useful species in revegetation programs.

Bouncing-bet has been useful in past reseeding programs in the Mountain Browse vegetation type (Plummer 1968) (Figure 43). It had excellent emergence in 1973, but declined in survival during the second growing season to a rating of fair to excellent (Table 4). In 1974 bouncing-bet demonstrated slightly better survival on the 4 to 1 northwest aspect. No difference was recorded between treatments.

Arrowleaf balsamroot was one of the best forbs at this location. It was native to this vegetation type and displayed excellent

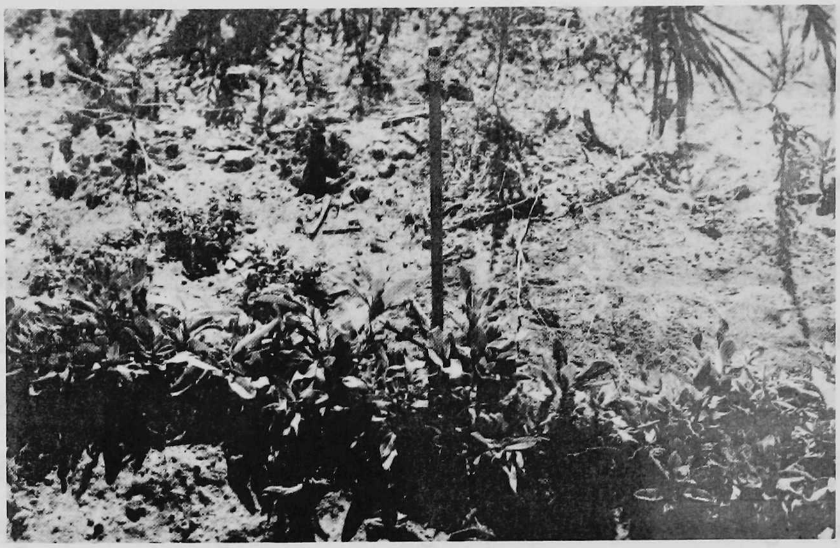


Figure 43. Bouncing-bet at Mountain Browse Location.

Figure 44. Black chokecherry at Mountain Browse Location.

emergence in 1973 and excellent survival in 1974. Statistically it was the same throughout the location during the first season of growth.

Browse

The browse species did not excell as well as the grasses and forbs at this location. Problems with dormancy, low quality seed, and the loss of seed to birds and rodents greatly reduced seedling emergence. During the first growing season, six browse species showed good to excellent emergence. During the second growing season the number that survived with good to excellent ratings dropped to four species (Table 4).

Common bladdersenna displayed good to excellent emergence in 1973, but declined during the second growing season to only fair survival (Table 4). The ratings were slightly better on the gentle northwest aspect than on the 4 to 1 slope during the first year, but the difference was not significant. Statistically plowing and scraping were the same throughout the location.

Desert bitterbrush demonstrated good to excellent emergence during the first growing season (Table 4). At this time plowing was significantly better ($P<.05$) than scraping on the gentle northwest exposure. During the second growing season the survival of desert bitterbrush declined to a fair rating caused primarily by heavy browsing by deer (Table 4). Plowing supported better survival than scraping on both sites.

Stansbury cliffrose displayed excellent emergence in 1973 (Table 4). In 1974 survival declined slightly to a rating of good to excellent (Table 4). In 1974 plowing aided survival of cliffrose on the gentle sloping more favorable aspect. The treatments were identical on the 4 to 1 aspect, but this site had better survival than the gentle sloping aspect.

Green ephedra was a species which emerged rapidly and had excellent emergence in 1973. Statistically the scraped treatment on the gentle sloping site performed better ($P<.05$) than the scraped treatment on the 4 to 1 aspect. Survival was reduced slightly during the second growing season and the species performed somewhat better on the 4 to 1 slope (Table 4).

Black chokecherry was one of the best browse plants at this location (Figure 44). Germination and emergence were rapid and excellent during 1973 on both sites and both treatments (Table 4). During the second growing season survival was again excellent throughout the plot (Table 4). Fortunately this species was not browsed by mule deer, therefore allowing better survival.

Antelope bitterbrush displayed the best emergence and survival of all browse species during the first two seasons of growth (Figure 45). It was rated excellent in 1973 and again in 1974 on all sites and treatments (Table 4). This species would be highly recommended for reclamation work in this vegetation zone.

Selected Species

Preliminary results indicate that surface disturbances in the Mountain Browse vegetaion type can be reclaimed without too much difficulty as long as the topsoil is in place. From this research

Figure 45. Antelope bitterbrush at Mountain Browse Location.

there are at least 29 species of grasses, forbs and browse which could be recommended for future revegetation projects.

Of these 29 species, 17 are native to either the Piceance Creek Basin or the western states. The native grasses were Critana thickspike wheatgrass, Sodar streambank wheatgrass, Barton western wheatgrass, Rosana western wheatgrass, mountain brome, C-43 basin wildrye, and green needlegrass. The forbs and legumes that were native included Penngift crownvetch, Utah sweetvetch, Lewis flax, sweetanise, Rocky Mountain penstemon, and arrowleaf balsamroot. Finally, the native browse species which displayed good to excellent emergence and survival during the second growing season were Stansbury cliffrose, green ephedra, black chokecherry, and antelope bitterbrush.

The number of browse species may seem limiting at this time, but a seeding which took place in the fall of 1973 has indicated some promise from species such as serviceberry and snowberry, which were not seeded in 1972.

Fall 1973 Seeding

The emergence data collected in the spring and summer of 1974, on the seeding which took place in September 1973, was representative of a very dry year. Precipitation has been below normal in 1974 and has therefore initiated less plant growth.

At the big sagebrush location there were 13 grasses which displayed good to excellent emergence during the first year of growth. These included: Nordan crested wheatgrass, Amur and Oahe intermediate wheatgrass, Siberian wheatgrass, Jose tall wheatgrass, Luna pubescent wheatgrass, slender wheatgrass, Sodar streambank wheatgrass, Critana thickspike wheatgrass, mountain brome, Manchar brome, Regar meadow brome, and Galleta.

Lutana cicer milkvetch, Penngift crownvetch, Lewis flax, Madrid yellow sweetclover, and Rocky Mountain penstemon were forbs and legumes which had good to excellent emergence. The browse species with good emergence were shadscale saltbush, Gardner saltbush, green ephedra, winterfat, and Stansbury cliffrose.

At the low elevation pinyon-juniper location the grasses which have shown the best emergence in the second seeding included: Nordan crested wheatgrass, Jose tall wheatgrass, Amur and Oahe intermediate wheatgrass, Sodar streambank wheatgrass, Siberian wheatgrass, Critana thickspike wheatgrass, Luna pubescent wheatgrass, slender wheatgrass, Rosana western wheatgrass, Sawki Russian wildrye, and Regar meadow brome.

The forbs and legumes which have displayed good to excellent emergence included Lewis flax, Penngift crownvetch, arrowleaf balsamroot, and Madrid yellow sweetclover. Finally, squawcarpet ceanothus was the only browse plant which had fair emergence.

At the high elevation pinyon-juniper location, the 1973 seeding was completely invaded by cheatgrass. The plowing and scraping treatments were reapplied in August, one month prior to seeding. Cheatgrass was desiminating seed at this time and the newly treated area received a large amount of this seed. Therefore, emergence at this location was extremely low due to competition and low soil water levels. The only grasses which had good emergence were Nordan crested wheatgrass, Luna pubescent wheatgrass, and Siberian wheatgrass. Other species had no emergence or poor to fair emergence.

The forbs and legumes were no better, as only arrowleaf balsamroot and Palmer penstemon displayed fair emergence. The browse species showed very low emergence with no species having a rating above poor.

The mountain browse location had much better results than the upper pinyon-juniper location. The grasses which had good to excellent emergence included: Nordan crested wheatgrass, Critana thickspike wheatgrass, Jose tall wheatgrass, Amur and Oahe intermediate wheatgrass, Sodar streambank wheatgrass, Siberian wheatgrass, C-30 western wheatgrass, Rosana western wheatgrass, Barton western wheatgrass, Luna pubescent wheatgrass, slender wheatgrass, mountain brome, Regar meadow brome, Manchar brome, Sawki Russian wildrye, C-43 basin wildrye, and orchard grass.

Forbs and legumes were slower to emerge than the grasses. Madrid yellow sweetclover, Lutana cicer milkvetch, silky lupine, and Utah sweetvetch were the only species which demonstrated good emergence. Finally, the browse species were rated poor to fair, with serviceberry, green ephedra, common bladdersenna, antelope bitterbrush, and black chokecherry being the best species.

Discussion for 1973 Seeding

It is important to keep in mind that the results presented are only preliminary. Although there is a great deal of confidence in the species previously discussed, true survival can not be determined until after the third or fourth growing season. Therefore, the data collected through the remainder of the second growing season and future growing seasons will be more meaningful. Nevertheless, the present results must not be ignored. They are still very important, in that they have supplied a list of species for each location which should be researched further and a list which can be eliminated from further study.

The treatments that were applied to each location have shown very little differences with respect to emergence and survival. Some species did show significantly better emergence and survival on one treatment over another, but the majority of species did not. The disturbances created were obviously not severe enough to be truly representative of roads, pipelines, construction sites, utility corridors or other surface disturbances created by a commercial oil shale industry. This is the primary reason that a significant difference was not prominent for the two treatments. Although the disturbances were not the actual disruptions that would be created during commercial development, they were severe enough to test species adaptability in different vegetation types on different aspects and slopes. If further work is carried out in this area, the use of more severe treatments may be desirable.

When a species does not germinate and emerge it is important to determine what factors are responsible. An unusually high amount of seed (150 seeds per linear meter) was planted in each row in order to insure some germination and emergence. The percent germination of the seed was not known at the time of seeding, therefore, a high seeding rate was necessary. Duirng the fall of 1973 a germination test was conducted for each species seeded (Appendix, Table 12). These results enabled us to explain why certain species did not perform as well as anticipated.

If the percent germination of a species was high and emergence was low than other factors must be taken into account. At the sagebrush and mountain browse locations, the competition from invading annual and perennial plants on the seeded areas had some influence on germination, growth, and vigor of certain plants. Competition for moisture and nutrients during the early stages of growth were also key factors affecting emergence.

Another factor responsible for reduced emergence was species adaptability. Some species were not adapted to a particular elevation, soil type or climate. Low moisture levels, along with alternate periods of wetting and drying from natural precipitation also caused poor germination.

Other factors affecting seedling emergence included: fall germination which resulted in winter kill, seeds rotting prior to germination from too much moisture, loss of seed to birds and rodents, not seeding at the proper depth, seeding warm season grasses in the fall instead of the spring, surface crusting of the soil, and finally, the attack by fungi and diseases on germinating seed.

If the species emerged, but did not survive, then other factors must enter the picture. Competition from invading plants can also reduce survival, along with low soil water levels, low nutrient levels in the soil, and grazing and browsing by domestic livestock and wild herbivores.

Natural Recovery and Control Areas

Although natural recovery is a slow process in semi-arid regions it is a very important process that must be considered during reclamation efforts. Primary and secondary succession will be responsible for developing the diverse vegetative ecosystems necessary to support various life forms that existed before disturbances took place.

Cover and biomass data were collected on both natural recovery and control areas at each location. Native control areas were analyzed to determine canopy cover and biomass of individual species for baseline data. Natural recovery areas were also analyzed for canopy cover and biomass in order to describe the stages of natural succession which have taken place following the application of each surface disturbance. The biomass data collected for grasses and forbs included the above ground standing crop, while shrubs and trees were measured only for the present year's growth.

The Appendix Tables (6-41) illustrate the biomass and canopy cover for each species found at each location on native control areas and on natural recovery areas in 1973 and 1974. Tables 6-14 are for the Mid-Elevation Sagebrush location while Appendix Tables 15-23, 24-32, and 33-41 are for the Low Elevation Pinyon-Juniper, the High Elevation Pinyon-Juniper, and Mountain Brush location, respectively.

Mid-Elevation Sagebrush Location

Beginning with the sagebrush location it was observed that the natural recovery areas displayed good recovery after two years with the majority of the species being grasses and forbs. The composition changed slightly between 1973 and 1974 with the invasion of new grasses, forbs, and browse species. After one year's growth the plowed areas were inhabitated primarily with western wheatgrass, Indian ricegrass, lambsquarters, Eriogonum spp., Knotweed, and scarlet globemallow. Douglas rabbitbrush and winterfat were also present, but in smaller quantities (Appendix Tables 7 and 8).

One year later the number of grasses increased, with western wheatgrass, Indian ricegrass, and needle-and-thread being the dominant grasses on both aspects. Squirreltail bottlebrush, Junegrass, Poa spp., and cheatgrass were also present. The number of forbs in 1974 also increased with white gilia, double bladderpod, scarlet globemallow, Russian thistle, cryptantha, and buckwheat being the dominant species. The browse species consisted of winterfat, Douglas rabbitbrush, shadscale saltbrush, and horsebrush. The natural invasion on the scraped areas was very similar to the plowed zones. The same grasses and browse were dominant, while the most abundant forbs consisted of phlox, white gilia, mustard, hairy goldenaster, buckwheat and scarlet globemallow (Appendix Tables 10, 11, 13, and 14).

Low Elevation Pinyon-Juniper Location

At the low elevation pinyon-juniper location substantial differences existed between the three aspects. In 1973, the plowed areas were dominated by Indian ricegrass, western wheatgrass, Lewis flax, white buckwheat, and phlox on the north slope. The ridge top was inhabited primarily by Indian ricegrass, western wheatgrass, phlox, rock aster, white buckwheat, winterfat, and serviceberry. Finally, the south slope was invaded by Indian ricegrass, western wheatgrass, mint, cryptantha, goldenweed, and white buckwheat (Appendix Table 16).

In 1974 the dominant grasses on all the plowed aspects were Indian ricegrass and western wheatgrass with needle-and-thread showing some invasion on the north slope and ridge top. The most abundant forbs and browse on the north slope consisted of cryptantha, goldenweed, Douglas rabbitbrush, and horsebrush. The dominant forbs and browse on the ridge top were Lewis flax, cryptantha, white gilia, horsebrush, and Douglas rabbitbrush. Finally, the south slope was inhabited primarily by mint, cryptantha, horsebrush, broom snakeweed, and Douglas rabbitbrush (Appendix Tables 19 and 22).

The scraped areas were only slightly different than the plowed zones in 1973 and 1974. After one year, the only grasses present on all three aspects were Indian ricegrass and western wheatgrass (Appendix Table 17). On the north slope the major forbs and browse consisted of goldenweed, evening primrose, broom snakeweed, and Douglas rabbitbrush. On the ridge top the dominant forbs were Russian thistle, evening primrose, and phlox. The south slope was also different, with the major species being bull thistle, double bladderpod, mint, service berry, and mountain mahogany.

In 1974 the grasses were the same as the previous year, but the forbs and browse showed some change. Cryptantha, goldenweed, Lewis flax, phlox, mint, Douglas rabbitbrush, and mountain mahogany dominated the north slope. On the ridge top the major species were Lewis flax, white gilia, double bladderpod, phlox, Douglas rabbitbrush, and mountain mahogany. Finally, the south slope was inhabited primarily by mint, cryptantha, double bladderpod, goldenweed, horsebrush, and mountain mahogany (Appendix Tables 20 and 23).

High Elevation Pinyon-Juniper Location

At the high elevation pinyon-juniper location only grasses and forbs invaded the plowed and scraped areas during 1973. The most dominant species on the plowed northwest slope were Indian ricegrass, western wheatgrass, lambsquarters, scarlet globemallow, and *Aster* spp. On the plowed south slope the species which were most abundant were Indian ricegrass, cheatgrass, false yarrow, lambsquarters, and stickseed (Appendix Table 25).

Western wheatgrass, Indian ricegrass, cheatgrass, beardless wheatgrass, *Aster* spp., lambsquarters, and false yarrow were the dominant species on the scraped northwest slope. Natural invasion on the south scraped slope consisted primarily of Indian ricegrass, cheatgrass, *Aster* spp., mustard, and double bladderpod (Appendix Table 26).

During 1974 natural succession continued with the invation of new grasses, forbs, and browse species. On the plowed northwest slope the most abundant species included Indian ricegrass, western wheatgrass, cheatgrass, big bluegrass, squirreltail bottlebrush, daisy fleabane, false yarrow, double bladderpod, red trumpet flower, snowberry, and antelope bitterbrush. Fewer species were recorded on the plowed south slope with only Indian ricegrass, cheatgrass, squirreltail bottlebrush, false yarrow, and red trumpet flower being most numerous (Appendix Tables 28 and 31).

On the scraped areas the dominant species on the northwest slope were Indian ricegrass, western wheatgrass, squirreltail bottlebrush, false yarrow, daisy fleabane, cryptantha, phlox, snowberry, winterfat, and horsebrush. Again, less species were present on the south slope with Indian ricegrass, squirreltail bottlebrush, cheatgrass, beardless wheatgrass, arrowleaf balsamroot, and daisy fleabane being the dominant species (Appendix Tables 29 and 32).

Mountain Browse Location

The mountain browse location had the most rapid successional development of all four vegetation types. A diverse group of grasses, forbs, and browse invaded the plowed and scraped areas in 1973 and 1974. The dominant species in 1973 on the plowed gentle slope included Junegrass, western wheatgrass, mountain brome, lupine, lambsquarters, wild pea, scarlet globemallow, Douglas rabbitbrush, serviceberry, big sagebrush, and antelope bitterbrush (Appendix Table 34).

The number of invading species was greater on the scraped areas due to the lesser degree of disturbance. The dominant species on the gentle slope were western wheatgrass, lupine, lambsquarters, _Eriogonum_ spp., arrowleaf balsamroot, snowberry, Douglas rabbitbrush, big sagebrush, and antelope bitterbrush. The steeper slope was invaded by mountain brome, western wheatgrass, lambsquarters, lupine, phlox, serviceberry, antelope bitterbrush, Douglas rabbitbrush, and big sagebrush (Appendix Table 35).

In 1974 the number of grasses and forbs increased substantially. Approximately 26 species were recorded on the plowed gentle slope with western wheatgrass, Indian ricegrass, big bluegrass, lupine, wild pea, _Euphorbia_ spp.,Douglas rabbitbrush, serviceberry, and snowberry being the dominant species. On the steeper slope the most abundant species were western wheatgrass, big bluegrass, needle-and-thread, lupine, Rocky Mountain penstemon, wild pea, Douglas rabbitbrush, serviceberry (Appendix Tables 37 and 40).

Finally, on the scraped, gentle slope the dominant invading species were western wheatgrass, big bluegrass, Indian ricegrass, lupine, arrowleaf balsamroot, wild pea, serviceberry, Douglas rabbitbrush and antelope bitterbrush. The steeper northwest slope was inhabited primarily with western wheatgrass, big bluegrass, lupine, groundsmoke, Euphorbia spp., wild pea, snowberry, serviceberry, Douglas rabbitbrush, and antelope bitterbrush.

Discussion for Natural Recovery

The stages of natural succession during the two years of data collection was more advanced than many past disturbances in the area. Comparing this information to the information presented by Terwilliger et al., (1974) it can be seen that natural succession proceeded at a faster rate due primarily to the degree of disturbance. In this experiment it must be remembered that a native seed source still remained after plowing and scraping were initiated. Underground root stalks were also present, which allowed resprouting of many browse species.

Natural rehabilitation of completely disturbed areas progresses through annual forb, grass-forb and shrub-grass stages of succession (Terwilliger, et al.1974). Final stages of succession develop more rapidly at higher elevations in the Piceance Basin than at lower elevations due primarily to more favorable growing conditions.

During the two years of this experiment, the natural stage of succession at the lower elevations appeared to be a a grass-forb stage, with some annual forbs. At the higher elevations the successional stage again appeared to be in a grass-forb stage, but progressing into a shrub-grass stage.

Natural rehabilitation will be an important part of future rehabilitation programs in the Piceance Basin. In order to reach complete rehabilitation some help from secondary succession will be imperative.

CONCLUSIONS AND RECOMMENDATIONS

Before any conclusions can be made it is necessary to re-examine the objectives of this research. Four major vegetation types within the Piceance Basin were selected, and then disturbed to create an environment suitable for studying species adaptability. A total of 81 species were seeded in order to determine adaptability within each vegetation type studied. Along with adaptability, species were selected for purposes of reducing wind and water erosion and developing suitable habitat for large herbivores.

Preliminary results indicate that there are a subset of these 81 species which could be recommended for future revegetation programs on the various sites studied. The group of plants suitable for each vegetation type includes both native and introduced grasses, forbs and browse. Depending on the future land use in the basin, seeding a mixture of either all native or native and introduced species would be the most logical procedure to follow.

The species that have shown to be the best adapted in each vegetation zone included plants that are suited to stabilizing eroding areas, and that are adapted for domestic livestock and big game habitats. Contained in these groups of plants were nitrogen fixing legumes, quick growing biennials and perennials, and rhizomatous species noted for their soil stabilizing ability.

Many recommendations can be made with regard to the continuation of this research and future rehabilitation projects in the Piceance Basin. To begin with it is essential to conduct a complete chemical analysis of the plant growth media to determine if this material is low in fertility or high in toxicity. If problematic areas are discovered, then the appropriate steps should be incorporated into future studies to overcome them.

When further research is conducted, it would be desirable to simulate more closely the actual disturbances that would take place under mining activity. During the construction of roads, pipelines and topsoiling overburden in some cases the subsoil and topsoil should be removed, stockpiled, and mixed in various fashions. Mixing should take place when this material is replaced, resulting in a completely new plant growth medium.

After the disturbance is completed other treatments may be applied. These could include: chiseling, gouging, pitting, contour furrowing, dozer basins, and other methods to reduce water flow, increase infiltration rates, and provide suitable seedbeds.

The use of mixtures would be the next step after species adaptability is determined. Seeding mixtures of species would be the best way to obtain a diverse as well as a more complete ecosystem, which should be a primary goal in any rehabilitation program.

Other practices, such as fertilizing, mulching, irrigating, transplanting, and the use of different methods of seeding, such as drilling and broadcasting can also be incorporated into future research.

Further recommendations would be to test species adaptability in still other vegetation zones within the Piceance Basin. Disturbances will occur in other vegetation types, such as the broad, flat valley bottoms dominated by greasewood. These areas have water tables at or near the surface with high salinity and alkalinity levels in the surface soil. Along with the Greasewood vegetation type, the High Elevation Grasslands and the Douglas fir and Aspen Forests are also potential areas to be disturbed or used for disposal of processed shale material. Species adaptability should be determined for these areas because the success or failure of any revegetation project relies heavily on the use of proper plant species.

Finally, proper management of the land following revegetation is essential. This should include fencing to exclude herbivore populations from consuming plant material during the first two to four years of growth. Also the addition of maintenance fertilizer when needed and irrigation during periods of drought will also be necessary.

SUMMARY

The grasses which showed the best adaptability at the big sagebrush location (1972 seeding) included various wheatgrasses such as Nordan crested, Critana thickspike, Jose tall, Amur and Oahe intermediate, Sodar streambank, Siberian, and Luna pubescent; along with mountain brome, Regar meadow brome and green needlegrass. The forbs and legumes which were most promising at this location included Madrid yellow sweetclover, bouncing-bet, Utah sweetvetch, Lewis flax, Rhizoma alfalfa, and Rocky Mountain penstemon. Along with the above grasses and forbs there were five browse species which also displayed superior emergence and survival: yellowbrush, Stansbury cliffrose, green ephedra, winterfat, and antelope bitterbrush.

At the low elevation pinyon-juniper location there were nine grasses, eight forbs and legumes, and three shrubs from the 1972 seeding which displayed good to excellent adaptability. The list of grasses included the following species: Nordan crested wheatgrass, Critana thickspike wheatgrass, Amur intermediate wheatgrass, Oahe intermediate wheatgrass, Sodar streambank wheatgrass, Rosana western wheatgrass, Luna pubescent wheatgrass, Regar meadow brome, and green needlegrass. Forbs and legumes which appeared to be promising during this study period were Penngift crownvetch, Utah sweetvetch, Lewis flax, Rhizoma alfalfa, Rambler alfalfa, Madrid yellow sweetclover, small burnet, and arrowleaf balsamroot. The number of browse species was more limited, with only yellowbrush, winterfat and green ephedra included in the list of recommended species.

Species adaptability at the high elevation pinyon-juniper location was better than the two previous locations. There were 12 grasses, 11 forbs and legumes, and seven shrubs that performed well enough to be recommended for future revegetation projects. The native and introduced grasses that were found to be superior during this study period included Nordan crested wheatgrass, Critana thick-spike wheatgrass, Jose tall wheatgrass, Amur intermediate wheatgrass, Oahe intermediate wheatgrass, Siberian wheatgrass, Rosana western wheatgrass, Luna pubescent wheatgrass, mountain brome, Regar meadow brome, Manchar brome, and green needlegrass. Native and introduced forbs and legumes which displayed good adaptability at the high elevation pinyon-juniper location were Penngift crownvetch, Madrid yellow sweetclover, sweetanise, Utah sweetvetch, Rhizoma alfalfa, Palmer penstemon, Rocky Mountain penstemon, bouncing-bet, Gooseberry-leaf globemallow, verbena, and arrowleaf balsamroot. Finally, the browse species that were highly recommended at this location included common bladdersenna, green ephedra, desert bitterbrush, antelope bitterbrush, yellowbrush, Stansbury cliffrose, and black chokecherry.

The grasses which displayed the best adaptability at the mountain browse location (1972 seeding) included various wheatgrasses such as: Nordan crested, Critana thickspike, Jose tall, Amur intermediate, Oahe intermediate, Sodar streambank, Siberian, Rosana western, Barton western, and Luna pubescent; along with mountain brome, Regar meadow brome, Manchar brome, C-43 basin wildrye, and green needlegrass. In addition to the grasses, the most promising forbs and legumes were Penngift crownvetch, Utah sweetvetch, Lewis flax, Rambler alfalfa, Rhizoma alfalfa, Madrid yellow sweetclover, sweetanise, Rocky Mountain penstemon, bouncing-bet and arrowleaf balsamroot.

The group of browse plants that was recommended for this location consisted of all native species. This group was composed of the following species: common bladdersenna, desert bitterbrush, antelope bitterbrush, Stansbury cliffrose, green ephedra, and black chokecherry.

The plants that have been recommended for each location were selected from the large group of species seeded in 1972. Information on emergence and survival was collected during two growing seasons before recommendations were made. These results are still preliminary and must be utilized with some degree of uncertainty. Further data will be needed before final conclusions can be made.

It was found that natural recovery on disturbed areas progressed through annual forb, grass-forb, and finally a shrub-grass stage. As would be expected, stages of succession develop more rapidly at higher elevations than at lower elevations because of more favorable growing conditions. The greater the severity of the disturbances the slower the rate of natural recovery. In most cases, complete rehabilitation will depend to some degree upon natural secondary succession even though soil preparation, fertilization and planting has taken place.

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APPENDIX

Table 1. List of scientific and common names of plant species referred to in the text.*

	Scientific Name	Common Name
Grasses		
1.	Agropyron cristatum, var. Nordan	Nordan crested wheatgrass
2.	Agropyron dasystachyum , var. Critana	Critana thickspike wheatgrass
3.	Agropyron elongatum, var. Jose	Jose tall wheatgrass
4.	Agropyron griffithsi	Griffiths wheatgrass
5.	Agropyron intermedium, var. Amur	Amur intermediate wheatgrass
6.	Agropyron intermedium, var. Oahe	Oahe intermediate wheatgrass
7.	Agropyron riparium, var. Sodar	Sodar streambank wheatgrass
8.	Agropyron sibiricum	Siberian wheatgrass
9.	Agropyron smithii	Bluestem wheatgrass
10.	Agropyron smithii var. Barton	Barton western wheatgrass
11.	Agropyron smithii var. C-30	C-30 western wheatgrass
12.	Agropyron smithii, var. Rosana	Rosana western wheatgrass
13.	Agropyron spicatum	Bearded bluebunch wheatgrass
14.	Agropyron spicatum inerme	Beardless bluebunch wheatgrass
15.	Agropyron trachycaulum	Slender wheatgrass
16.	Agropyron trichophorum, var. Luna	Luna pubescent wheatgrass
17.	Bromus carinatus	Mountain brome
18.	Bromus erectus, var. Regar	Regar meadow brome
19.	Bromus inermis	Manchar brome
20.	Bromus tectorum	Cheatgrass
21.	Dactylis glomerata	Orchardgrass
22.	Elymus cinereus, var. C-43	C-43 basin wildrye
23.	Elymus junceus, var. Sawki	Sawki Russian wildrye
24.	Elymus salinus	Salina wildrye
25.	Festuca arizonica	Arizona fescue
26.	Festuca ovina duriuscula	Hard sheep fescue
27.	Festuca ovina, var. Durar	Durar hard fescue
28.	Festuca sulcata	Sulcata sheep fescue
29.	Hilaria jameseii	Galleta hilaria
30.	Hordeum jubatum	Foxtail barley
31.	Koeleria cristata	Junegrass
32.	Oryzopsis hymenoides	Indian ricegrass
33.	Phleum pratense	Timothy
34.	Poa ample, var. Shermans	Shermans big bluegrass
35.	Poa pratensis	Kentucky bluegrass
36.	Sitanion hystrix	Bottlebrush squirreltail
37.	Sporobolus airoides	Alkali sacaton
38.	Sporobolus cryptandrus	Sand dropseed
39.	Stipa comata	Needle and thread
40.	Stipa viridula	Green needlegrass

Table 1. (Continued)

	Scientific Name	Common Name
Forbs		
1.	Allium cernum	Nodding onion
2.	Antennaria rosea	Rose pussytoes
3.	Aster arenosus	Smallflower aster
4.	Aster chilensis adscendens	Pacific aster
5.	Aster spp.	Aster
6.	Aster spp.	Rock aster
7.	Astragalus cicer	Chicken milkvetch
8.	Astragalus cicer, var. Lutana	Lutana cicer milkvetch
9.	Astragalus falcatus	Sicklepod milkvetch
10.	Astragalus galegiformis	Tall milkvetch
11.	Astragalus spp.	Loco
12.	Balsamorhiza sagittata	Cutleaf arrowleaf balsamroot
13.	Bellis spp.	Spreading daisy
14.	Brassica spp.	Mustard
15.	Castilleja spp.	Indian paintbrush
16.	Chaenactic spp.	False yarrow
17.	Chenopodium album	Lambsquarters
18.	Chrysopsis spp.	Hairy goldaster
19.	Cirsium spp.	Bull thistle
20.	Coronfila varia, var. Penngift	Penngift crownvetch
21.	Crepis spp.	Hawksbeard
22.	Cryptantha sericea	Cryptantha
23.	Erigeron strigosus	Daisy flebane
24.	Eriogonum spp.	Wild buckwheat
25.	Eriogonum umbellatum	Sulphur buckwheat
26.	Eriogonum wrightii	White buckwheat
27.	Erysimum spp.	Western wallflower
28.	Gayophytum spp.	Ground smoke
29.	Gilia androsacea	Red trumpet flower
30.	Gilia leucophylla	White gilia
31.	Hedysarum boreale utahensis	Utah sweetvetch
32.	Lappula redowski	Stickseed
33.	Lesquerella spp.	Bladderpod
34.	Linum lewisii	Lewis flax
35.	Lupinus alpestris	Mountain lupine
36.	Lupinus nevadensis	Nevada lupine
37.	Lupinus sericeus	Silky lupine
38.	Medicago sativa, var. Rambler	Rambler alfalfa
39.	Medicago sativa, var. Rhizoma	Rhizoma alfalfa
40.	Melilotus officinalis, var. Madrid	Madrid yellow sweetclover
41.	Metha spp.	Mint
42.	Oenothera spp.	Evening primrose
43.	Osmorhiza occidentalis	Sweetanise
44.	Penstemon palmeri	Palmer penstemon
45.	Penstemon strictus	Rocky mountain penstemon
46.	Petalostemon purporeum	Purple prairie clover
47.	Phlox cacapitosa	Low phlox
48.	Phlox hoodii	Hood phlox
49.	Phlox spp.	Phlox
50.	Pisum spp.	Wild pea

	Scientific Name	Common Name
51.	Polygonum spp.	Knotweed
52.	Salsola kali	Russian thistle
53.	Sanguisorba minor	Small burnet
54.	Saponaria officinalis	Bouncing-bet
55.	Sphaeralcea coccinea	Scarlet globemallow
56.	Sphaeralcea grossulariaefolia	Gooseberryleaf globemallow
57.	Taraxacum spp.	Dandelion
58.	Townsendia spp.	Towensendia
59.	Tragopogon dubius	Yellow salsify
60.	Verbena sp.	Verbena
Shrubs		
1.	Amelanchier alnifolia	Saskatoon serviceberry
2.	Amelanchier utahensis	Utah serviceberry
3.	Artemisia arbuscula nova	Black sagebrush
4.	Artemisia frigida	Fringed sagebrush
5.	Artemisia tridentata	Big sagebrush
6.	Atriplex canescens	Fourwing saltbush
7.	Atriplex confertifolia	Shadscale saltbush
8.	Atriplex gardneri	Gardner saltbush
9.	Atriplex nuttallii	Nuttall saltbush
10.	Ceanothus integerrimus	Ceanotha-deerbrush
11.	Ceanothus prostratus	Squawcarpet
12.	Cercocarpos betuloides	Birchleaf mountain mahogany
13.	Cercocarpos montanus	True mountain mahogany
14.	Chrysothamnus nauseosus	Rubber rabbitbrush
15.	Chrysothamnus viscidiflorus	Douglas rabbitbrush
16.	Chrysothamnus viscidiflorus lanceolatus	Yellowbrush
17.	Colubrina arborescens	Common bladdersenna
18.	Cowania mexicana stansburiana	Stansbury cliffrose
19.	Elaeagnus angustifolia	Russian olive
20.	Ephedra viridis	Green ephedra
21.	Eurotia lanata	Winterfat
22.	Forestiera neomexicana	New Mexico forestiera
23.	Gutierrezia sarothrae	Broom snakeweed
24.	Ilex verticillata	Winterberry
25.	Kochia vestita	Desert molly (Gray summercypress)
26.	Prunus fasciculata	Desert peachbrush
27.	Prunus virginiana melanocarpa	Black chokecherry
28.	Purshia glandulosa	Desert bitterbrush
29.	Purshia tridentata	Antelope bitterbrush
30.	Rhus trilobata	Skunkbush sumac
31.	Sarcobatus vermiculatus	Greasewood
32.	Sambucus caerulea	Blueberry elder
33.	Shepherdia argentea	Silver buffaloberry
34.	Symphoricarpos albus	Snowberry
35.	Symphoricarpos longiflorus	Longflower snowberry
36.	Symphoricarpos oreophilus	Mountain snowberry
37.	Symphoricarpos rivularis	Garden snowberry
38.	Tetradymia canescens	Horsebrush
Trees		
1.	Juniperus osteosperma	Utah juniper
2.	Pinus monophylla	One-leaf pinyon

*Beetle 1970; Hudson et al 1973; Plummer 1968; Soil Conservation Service 1971.

Table 2. List of scientific and common names of plant species seeded at four locations.

Scientific Name	Common Name
Grasses	
1. Agropyron cristatum, var. Nordan	Nordan crested wheatgrass
2. Agropyron dasystachyum, var. Critana	Critana thickspike wheatgrass
3. Agropyron elongatum, var. Jose	Jose tall wheatgrass
4. Agropyron griffithsi	Griffiths wheatgrass
5. Agropyron intermedium, var. Amur	Amur intermediate wheatgrass
6. Agropyron intermedium, var. Oahe	Oahe intermediate wheatgrass
7. Agropyron riparium, var. Sodar	Sodar streambank wheatgrass
8. Agropyron sibiricum	Siberian wheatgrass
9. Agropyron smithii	C-30 Western wheatgrass
10. Agropyron smithii, var. Barton	Barton western wheatgrass
11. Agropyron smithii, var. Rosana	Rosana western wheatgrass
12. Agropyron spicatum	Bluebunch wheatgrass
13. Agropyron trachycaulum	Slender wheatgrass
14. Agropyron trichophorum, var. Luna	Luna pubescent wheatgrass
15. Bromus carinatus	Mountain brome
16. Bromus erectus, var. Regar	Regar meadow brome
17. Bromus inermis	Manchar brome
18. Dactylis glomerata	Orchardgrass
19. Elymus cinereus, var. C-43	C-43 basin wildrye
20. Elymus junceus, var. Sawki	Sawki Russian wildrye
21. Elymus salinus	Salina wildrye
22. Festuca arizonica	Arizona fescue
23. Festuca ovina, var. Durar	Durar hard fescue
24. Hilaria jamesii	Galleta hilaria
25. Oryzopsis hymenoides	Indian ricegrass
26. Phleum pratense	Timothy
27. Poa ampla, var. Shermans	Shermans big bluegrass
28. Poa pratensis	Kentucky bluegrass
29. Sporobolus airoides	Alkali sacaton
30. Sporobolus cryptandrus	Sand dropseed
31. Stipa viridula	Green needlegrass
Forbs	
1. Aster chilensis adscendens	Pacific aster
2. Aster sp.	Aster
3. Astragalus cicer, var. Lutana	Lutana cicer milkvetch
4. Astragalus falcatus	Sicklepod milkvetch
5. Coronilla varia, var. Penngift	Penngift crownvetch
6. Hedysarum utahensis	Utah sweetvetch
7. Linum lewisii	Lewis flax
8. Lupinus alpestris	Mountain lupine
9. Medicago sativa, var. Rambler	Rambler alfalfa
10. Medicago sativa, var. Rhizoma	Rhizoma alfalfa
11. Melilotus officinalis, var. Madrid	Madrid yellow sweetclover
12. Osmorhiza occidentalis	Sweetanise
13. Penstemon palmeri	Palmer penstemon
14. Penstemon strictus	Rocky mountain penstemon
15. Petalostemon purpureum	Purple prairie clover
16. Sanguisorba minor	Small burnet
17. Saponaria officinalis	Bouncing-bet
18. Sphaeralcea grossulariaefolia	Gooseberryleaf globemallow
19. Verbena sp.	Verbena
20. Balsamorhiza sagittata	Arrowleaf balsamroot

Table 2. (Continued)

	Scientific Name	Common Name
Shrubs		
1.	Amelanchier utahensis	Serviceberry
2.	Artemisia arbuscula nova	Black sagebrush
3.	Artemisia tridentata	Big sagebrush
4.	Atriplex canescens	Fourwing saltbush
5.	Atriplex confertifolia	Shadscale saltbush
6.	Atriplex gradneri	Gardner saltbush
7.	Atriplex nuttallii	Nuttall saltbush
8.	Ceanothus integerrimus	Ceanothus - deerbrush
9.	Ceanothus prostratus	Ceanothus - squawcarpet
10.	Cercocarpus betuloides	Birchleaf Mt. Mahogany
11.	Cercocarpus ledifolius	Curl-leaf Mt. Mahogany
12.	Cercocarpus montanus	True mountain mahogany
13.	Chrysothamnus nauseosus	Rubber rabbitbrush
14.	Chrysothamnus viscidiflorus	Yellowbrush
15.	Colubrina arborescens	Common bladdersenna
16.	Cowania stansburiana	Stansbury cliffrose
17.	Elaeagnus angustifolia	Russian-olive
18.	Ephedra viridis	Green ephedra
19.	Eurotia lanata	Winterfat
20.	Forestiera neomexicana	New Mexico forestiera
21.	Ilex verticillata	Winterberry
22.	Kochia vestita	Desert molly
23.	Prunus fasciculata	Desert peachbrush
24.	Prunus virginiana melanocarpa	Black chokecherry
25.	Purshia galndulosa	Desert bitterbrush
26.	Purshia tridentata	Antelope bitterbrush
27.	Rhus trilobata	Skunkbush sumac
28.	Sambucus caerulea	Blueberry elder
29.	Shepherdia argentea	Silver Buffaloberry
30.	Symphoricarpos albus	Snowberry

Table 3. Percent germination of species seeded at four locations.

Common Name	Percent Germination
Grasses	
Nordan crested wheatgrass	95.0
Critana thickspike wheatgrass	88.0
Jose tall wheatgrass	97.7
Griffiths wheatgrass	4.8
Amur intermediate wheatgrass	88.0
Oahe intermediate wheatgrass	90.7
Sodar streambank wheatgrass	98.0
Siberian wheatgrass	93.2
C-30 Western wheatgrass	85.7
Barton western wheatgrass	79.8
Rosana western wheatgrass	89.3
Bluebunch wheatgrass	94.5
Slender wheatgrass	96.7
Luna pubescent wheatgrass	95.5
Mountain brome	88.2
Regar meadow brome	88.0
Manchar brome	89.7
Orchardgrass	88.8
C-43 basin wildrye	60.0
Sawki Russian wildrye	92.5
Salina wildrye	6.5
Arizona fescue	31.0
Durar hard fescue	62.5
Galleta hilaria	82.1
Indian ricegrass	56.0
Timothy	91.0
Shermans big bluegrass	61.5
Kentucky bluegrass	77.0
Alkali sacaton	65.8
Sand dropseed	37.5
Green needlegrass	96.0
Forbs	
Pacific aster	16.0
Aster	7.5
Lutana ciser milkvetch	76.8
Sicklepod milkvetch	12.0 and 33.5
Penngift crownvetch	73.3
Utah sweetvetch	86.5
Lewis flax	46.0
Mountain lupine	9.5
Rambler alfalfa	90.8
Rhizoma alfalfa	93.3
Madrid yellow sweetclover	92.3
Sweetanise	89.5
Palmer penstemon	88.3
Rocky mountain penstemon	80.3
Purple prairie clover	67.5

Table 3. (Continued)

Common Name	Percent Germination
Small burnet	89.8
Bouncing-bet	77.3
Gooseberryleaf globemallow	49.0
Verbena	88.8
Arrowleaf balsamroot	98.5
Shrubs	
Serviceberry	80.8
Black sagebrush	9.8
Big sagebrush	6.8
Fourwing saltbush	16.3
Shadscale saltbush	4.0 and 10.8
Gardner saltbush	74.0
Nuttall saltbush	63.0
Ceanothus - deerbrush	69.3
Ceanothus - squawcarpet	78.0
Birchleaf Mt. Mahogany	52.5
Curl-leaf Mt. Mahogany	55.8
True mountain mahogany	66.0
Rubber rabbitbrush	14.8
Yellowbrush	58.8
Common bladdersenna	80.8
Stansbury cliffrose	87.5
Russian-olive	85.0
Green ephedra	90.3
Winterfat	80.3
New Mexico forestiera	14.5
Winterberry	29.3
Desert molly	8.8
Desert peachbrush	89.3
Black chokecherry	68.3
Desert bitterbrush	84.0
Antelope bitterbrush	87.5
Skunkbush sumac	23.3
Blueberry elder	6.0
Silver Buffaloberry	63.8
Snowberry	85.8

Table 4. Soil survey for each location, including soil morphology and taxonomic units.

Low Pinyon-Juniper Location NE¼, SE¼, SE¼, Sec. 20, T1N, R97W.

This soil is within the range of the Penrose series of the Lithic Ustic Torriorthents, subgroup and loamy, mixed, calcareous, mesic family.

Sagebrush Location (A) SE¼, NE¼, SE¼, Sec. 24, T1S, R99W.

This soil is within the Baculan series and with a sandstone substratum variant. It also would only be in the Ustic Torriorthent subgroup and sandy skeletal, mixed, mesic family.

Sagebrush Location (B) SE¼, NE¼, SE¼, Sec. 24. T1S, R99W.

This soil is within the range of the Kim series which is in the Ustic Torriorthent subgroup and fine loamy, mixed (calcareous), mesic family.

High Pinyon-Juniper Location NE¼, SE¼, NE¼, Sec. 13, T3S, R97W.

This soil is within the Nihill series--cold variant, of the Ustic Torriorthent subgroup and loamy skeletal, mixed, calcareous, frigid family.

Mountain Brush Location NE¼, NE¼, NW¼, Sec. 14, T4S, R97W.

This soil is within the Cheadle series of the Lithic Cryoborolls subgroup and loamy skeletal, mixed family.

Soil Profile -- Low Pinyon-Juniper Location

A-1 0 to 3 cm Pale brown (10YR 6/3) channery loam, brown (10YR 4/3) moist; moderate and coarse grandular structure, soft dry, very friable moist, slightly sticky; calcareous; abrupt smooth boundary. (pH 8.6).

C-1 3 to 11 cm Pale brown (10YR 6/3) channery silt loam, dark yellowish brown (10YR 4/4) moist; moderate very coarse platy breaking to moderate medium and coarse subangular blocky structure; slightly hard dry, friable moist, slightly sticky slightly plastic, strongly calcareous; abrupt smooth boundary. (pH 8.8).

CR 11 to 24 cm White (10YR 8/1) dry, lime coating on brownish yellow to yellowish brown fractured and weathered platy shale rock.

R 24 cm+ Very hard and almost solid platy shale bedrock.

Remarks: The surface has about 30 to 50% cover of small channery chips ¼ to 1 inch in size and 1/16 to 3/16 inches thick. The A-1 and C-1 horizons contain many very fine visicular pores. The C-1 horizon also contains 15 to 30% of channery chips. The percent and thickness of the channery fragments will increase on the steep sideslopes of the ridges. The shale fragments in the CR and R horizons are lime coated and mainly on the underside.

Soft Provile-A -- Sagebrush Location -- Near center and 50 feet from the west end of plot.

A-11 0 to 6 cm Pale brown (10YR 6/3) gravelly fine sandy loam, brown (10YR 4/3) moist; platy surface crust 1 to 2 cm thick with many visicular pores plus moderate medium subangular blocky structure breaking to moderate medium and coarse granular; soft dry, very friable moist, slightly sticky; calcareous; clear smooth boundary; (pH 8.4).

A-12 6 to 13 cm Light brownish gray (2.5 YR 6/3) channery loamy fine sand, olive brown (2.5YR 4/4) moist; weak medium subangular blocky structure; soft dry, very friable; calcareous; abrupt smooth boundary; (pH 8.6).

C-1 13 to 32 cm Colors as horizon above; extremely weathered channery sandstone with lime coatings on underside turning into loamy sand; with moderate fine and medium platy structure; slightly hard dry; firm moist; strongly calcareous; abrupt smooth boundary; (pH 8.2).

CR 32 to 60 cm Pale Yellow (2.5YR 7/4) coarse channery very fine sandy loam and fine sandy loam, light yellowish brown (2.5YR 6/4) moist; rock structure; soil soft dry, friable moist, slightly sticky; strongly calcareous; (pH 9.4).

R 60 cm+ Colors same as horizon above; weathered and slightly fractured sandstone bedrock.

Remarks: The surface has a 15 to 30% cover of sandstone channery chips. The A-11 and A-12 horizons contain 20 to 35% channery fragments 1/8 to 1 inch in size and thickness. The C-1 horizon is a coarse channery.

Table 4. (Continued)

Soil Profile B -- Sagebrush Location -- Near center and 50 feet from the east end of plot.

A-11	0 to 4 cm Pale brown (10YR 6/3) loam, dark yellowish brown (10YR 4/4) moist; surface crusted with moderate coarse platy, breaking to moderate medium and coarse subangular blocky structure; slightly hard dry, friable moist, slightly sticky, slightly plastic; weakly calcareous; abrupt smooth boundary. (pH 8.0).
A-12	4 to 9 cm Brown (10YR 5/3) loam, dark yellowish brown (10YR 3/4) moist; weak medium and coarse subangular blocky structure; slightly hard, friable, slightly sticky, slightly plastic; weakly calcareous; clear smooth boundary; (pH 8.4).
C-1ca	9 to 38 cm White (2.5YR 8/2) heavy loam, pale yellow (2.5YR 7/4) moist; moderate medium subangular blocky structure; slightly hard dry; friable moist, sticky, plastic; strongly calcareous; clear smooth boundary; (pH 9.4).
11-C2ca	38 to 52 cm Light gray (2.5YR 7/2) channery silt loam, light yellowish brown (2.5YR 6/4) moist; massive breaking to weak coarse subangular blocky structure; slightly hard dry, friable moist, sticky, slightly plastic; strongly calcareous; clear smooth boundary; (pH 9.6).
CR	52 to 74 cm Light yellowish brown (2.5YR 6/4) coarse shannery and fine sandy loam, light olive brown (2.5YR 5/4) moist; weathered fractured sandstone, calcareous; gradual smooth boundary; (pH 9.2).
R	74 cm+ Weathered and fractured sandstone bedrock.
Remarks:	The A-11 horizon contains many visicular pores. The 11-C2ca contains 15 to 20% by volume channery fragments 1/4 to 1 inch in size and thickness. The CR horizon contains 40 to 65% of channery sandstone that ranges from 1/2 to 1-1/2 inches thick and 1 to 3 inches across.

Soil Profile -- High Pinyon-Juniper Location

A-11	0 to 10 cm Brown (10YR 4/3) light loam, very dark grayish brown (10YR 3/2) moist; weak medium subangular blocky, breaking to moderate very fine to medium granular structure, soft dry, very friable moist, slightly sticky; noncalcareous; clear smooth boundary; (pH 8.4).
A-12	10 to 18 cm Grayish brown (10YR 5/2) light loam, dark brown (10YR 3/3) moist; weak to moderate medium and coarse subangular blocky structure; slightly hard dry, very friable moist; slightly sticky; weakly calcareous; clear smooth boundary; (pH 8.6).
C-2ca	18 to 40 cm Light brownish gray (2.5YR 6/2) channery, very fine sandy loam, grayish brown (2.5YR 5/2) moist; massive breaking to weak medium and coarse subangular blocky structure; slightly hard dry, very friable moist, slightly sticky; strongly calcareous; gradual smooth boundary; (pH 8.6).
CR	40 to 56 cm Light gray (2.5YR 7/2) lime coated weathered and fractured sandstone with some soil in cracks.
R	56 cm+ Sandstone bedrock. (Somewhat fractured).
Remarks:	Where the A horizon has been removed the surface has a channery cover of 20 to 30% and will range in size of 1/4 to 3 inches and 1/4 to 1 inch thick. The C-2ca horizon has 40 to 65% sandstone channery 1/4 to 2 inches across and 1/4 to 1 inch thick.

Soil Profile -- Mountain Brush Location

A-11	0 to 3 cm Grayish brown (10YR 5/2) very fine sandy loam, very dark grayish brown (10YR 3/2) moist; moderate medium to very coarse platy, breaking to weak to moderate fine and medium subangular blocky structure; soft dry, very friable moist, slightly sticky, slightly plastic, noncalcareous; abrupt smooth boundary; (pH 7.2).
A-12	3 to 12 cm Colors same as horizon above; loam; moderate medium subangular blocky structure; slightly hard dry, friable, slightly sticky, slightly plastic; noncalcareous; clear smooth boundary; (pH 7.2).
CR	12 to 22 cm Colors same as horizons above; channery loam, rock structure; (pH 7.4).
R	22 cm+ Pale brown to light yellowish brown sandstone (pH 7.6).
Remarks:	Channery fragments are found throughout and on the surface.

Table 5. Precipitation data recorded at the four locations between October 23, 1970 and July 12, 1974.

	Sampling Period					
	10/23/72 to 6/20/73	6/20/73 to 8/28/73	8/28/73 to 9/19/73	9/19/73 to 12/11/73	12/11/73 to 6/12/74	6/12/74 to 7/12/74
Sagebrush	25.1*	8.4	1.5	6.9	15.4	0.0
Low Pinyon-Juniper	29.5	8.4	5.6	5.6	13.9	0.0
High Pinyon-Juniper	29.5	4.1	4.3	6.9	21.0	0.0
Mountain Browse	37.8	6.9	0.0	...**	21.0	0.0

* Measurements in centimeters
**Data not collected because of unfavorable weather.

Table 6. Biomass and canopy cover by species for the native control zones at the sagebrush location. Data collected on August 28, 1973.

Level Slope			West Slope		
Species	Kg/hec	% Cover	Species	Kg/hec	% Cover
Grasses			Grasses		
Cheatgrass	80	12	Western wheatgrass	123	8
Needle-and-thread	59	3	Indian ricegrass	82	5
Western wheatgrass	55	3	Needle-and-thread	52	4
Sheep fescue	23	1	Cheatgrass	48	4
Junegrass	15	2	Blue grama	24	2
Indian ricegrass	14	1	Beardless wheatgrass	13	<1
Squirreltail bottlebrush	8	1	Sheep fescue	4	<1
			Junegrass	2	<1
Forbs			Forbs		
Phlox	175	4	Phlox	142	2
Goldenweed	81	3	Goldenweed	87	5
Scarlet globemallow	65	5	Wild buckwheat	59	3
Lambsquarters	20	1	Scarlet globemallow	40	2
Lichen	9	1	Lichen	24	1
			False yarrow	2	<1
			Townsendia	2	<1
			Double bladderpod	1	<1
Browse			Browse		
Big Sagebrush	409	22	Big sagebrush	289	4
Douglas rabbitbrush	80	2	Douglas rabbitbrush	39	2
Prickly pear cactus	8	<1	Winterfat	30	2
			Broom snakeweed	11	<1
			Fringed sagebrush	6	<1

Table 7. Biomass and canopy cover by species for the plowed natural recovery zones at the sagebrush location. Data collected on August 28, 1973.

Level Slope			West Slope		
Species	Kg/hec	% Cover	Species	Kg/hec	% Cover
Grasses			Grasses		
Western wheatgrass	96	5	Indian ricegrass	52	2
Indian ricegrass	53	4	Western wheatgrass	27	1
Cheatgrass	5	<1			
Forbs			Forbs		
Lambsquarters	217	10	Erigonum spp.	167	7
Scarlet globemallow	98	4	Knotweed	143	5
Phlox	17	<1	Lambsquarters	45	1
Groundsmoke	15	2	Buckwheat	38	1
Milkuetch	2	<1	Milkvetch	35	2
			Goldenweed	22	1
			Double bladderpod	11	1
			False yarrow	8	<1
			Mustard	7	<1
			Smallflower aster	5	1
Browse			Scarlet globemallow	4	<1
Douglas rabbitbrush	2	<1	Phlox	3	<1
			Browse		
			Douglas rabbitbrush	20	1
			Winterfat	17	1

Table 8. Biomass and canopy cover by species for the scraped natural recovery zones at the sagebrush location. Data collected on August 28, 1973.

Level Slope			West Slope		
Species	Kg/hec	% Cover	Species	Kg/hec	% Cover
Grasses			Grasses		
Western wheatgrass	109	9	Western wheatgrass	44	3
Indian ricegrass	24	1	Indian ricegrass	21	2
Cheatgrass	3	<1			
Forbs			Forbs		
Scarlet globemallow	199	7	Eriogonum spp.	137	7
Lambsquarters	68	2	Knotweed	22	1
Phlox	42	1	Lambsquarters	13	<1
Goldenweed	15	<1	Scarlet globemallow	12	1
Knotweed	11	<1	Goldenweed	11	1
Lichen	9	<1	Phlox	11	<1
False Yarrow	2	<1	False yarrow	4	<1
Townsendia	2	<1	Smallflower aster	2	<1
Eriogonum spp.	1	<1	Double bladderpod	2	<1
Browse			Browse		
Big sagebrush	28	<1	Prickly pear cactus	23	<1
Douglas rabbitbrush	8	<1	Douglas rabbitbrush	5	<1
			Horsebrush	4	<1
			Shadscale saltbrush	4	<1

Table 9. Biomass and canopy cover by species for the native control zones at the sagebrush location. Data collected on June 20, 1974.

Level Slope

Species	Kg/hec	% Cover
Grasses		
Indian ricegrass	72	4
Poa spp.	40	2
Western wheatgrass	38	1
Junegrass	35	2
Squirreltail bottlebrush	34	2
Needle-and-thread	21	2
Cheatgrass	17	2
Forbs		
Phlox	100	3
Scarlet globemallow	27	2
Lichen	21	1
Hairy goldenaster	19	1
Spreading daisy	5	<1
Wild pea	3	<1
Cryptantha	1	<1
Browse		
Big sagebrush	508	20
Douglas rabbitbrush	31	1

West Slope

Species	Kg/hec	% Cover
Grasses		
Needle-and-thread	92	5
Western wheatgrass	46	3
Indian ricegrass	20	1
Junegrass	14	<1
Cheatgrass	6	<1
Forbs		
Phlox	109	3
Hairy goldenaster	45	2
Lichen	42	1
Mustard	29	1
White gilia	12	1
Scarlet globemallow	9	<1
Loco	6	<1
Astragalus spp.	5	<1
False yarrow	5	<1
Senecio spp.	1	<1
Browse		
Big sagebrush	116	4
Douglas rabbitbrush	73	2
Winterfat	6	<1

Table 10. Biomass and canopy cover by species for the plowed natural recovery zones at the sagebrush location.

Data collected on June 20, 1974.

Level Slope			West Slope		
Species	Kg/hec	% Cover	Species	Kg/hec	% Cover
Grasses			**Grasses**		
Indian ricegrass	260	14	Indian ricegrass	83	4
Western wheatgrass	190	9	Needle-and-thread	21	2
Needle-and-thread	83	7	Western wheatgrass	6	<1
Poa spp.	62	3	Cheatgrass	3	<1
Squirreltail bottlebrush	20	2	Junegrass	2	<1
Cheatgrass	17	1			
Junegrass	6	<1	**Forbs**		
			White gilia	221	12
			Double bladderpod	68	3
			Cryptantha	50	4
Forbs			Milkvetch	40	2
Russian thistle	65	4	Mustard	19	1
Scarlet globemallow	59	8	Phlox	18	1
Phlox	38	1	False yarrow	17	1
Spreading daisy	8	1	Scarlet globemallow	12	1
Groundsmoke	8	2	Hairy goldenaster	10	1
Dandelion	6	1	Wild pea	8	1
Wild pea	6	<1	Loco	5	<1
Phlox	5	<1	Dandelion	3	<1
Lichen	5	<1	Daisy	3	<1
Wild onion	3	<1	Lichen	3	<1
			Wild onion	2	<1
Browse			Senecio	2	<1
Douglas rabbitbrush	39	1	**Browse**		
			Winterfat	61	3
			Douglas rabbitbrush	18	1
			Shadscale saltbrush	1	<1

Table 11. Biomass and canopy cover by species for the scraped natural recovery cones at the sagebrush location. Data collected on June 19, 1974.

Level Slope

Species	Kg/hec	% Cover
Grasses		
Western wheatgrass	159	10
Indian ricegrass	85	6
Needle-and-thread	54	6
Junegrass	8	<1
Poa spp.	2	<1
Forbs		
Phlox	133	5
Scarlet globemallow	104	10
White gilia	46	2
Hairy goldenaster	32	2
Cryptantha	21	1
Lichen	17	<1
Spreading daisy	16	<1
Double bladderpod	13	<1
False yarrow	8	<1
Wild onion	2	<1
Mustard	1	<1
Browse		
Douglas rabbitbrush	90	2
Prickly pear cactus	25	1
Shadscale saltbrush	<1	<1

West Slope

Species	Kg/hec	% Cover
Grasses		
Western wheatgrass	91	5
Indian Ricegrass	53	3
Needle-and-thread	24	1
Cheatgrass	2	<1
Forbs		
White gilia	174	10
Mustard	71	4
Hairy goldenaster	41	2
False yarrow	31	1
Cryptantha	19	1
Scarlet globemallow	18	1
Lcco	15	1
Astragalus spp.	13	1
Double bladderpod	13	1
Lichen	11	<1
Phlox	9	<1
Wild pea	5	<1
Wild onion	5	<1
Spreading daisy	3	<1
Browse		
Winterfat	24	1
Douglas rabbitbrush	9	<1
Shadscale saltbush	2	<1

Table 12. Biomass and canopy cover by species for the native control zones at the sagebrush location. Data collected on August 30, 1974.

Level Slope			West Slope		
Species	Kg/hec	% Cover	Species	Kg/hec	% Cover
Grasses			Grasses		
Needle-and-thread	217	6	Indian ricegrass	73	2
Indian ricegrass	68	2	Needle-and-thread	65	2
Poa spp.	66	3	Blue grama	53	2
Western wheatgrass	61	2	Western wheatgrass	46	1
Cheatgrass	11	<1	Beardless wheatgrass	18	1
			Poa spp.	2	<1
Forbs			Forbs		
Phlox	94	3	Phlox	115	3
Scarlett globemallow	29	2	Buckwheat	61	3
Lichen	27	<1	Lichen	58	1
Hairy goldenaster	24	1	Hairy goldenaster	41	2
Buckwheat	1	<1	White gilia	10	1
Milkvetch	1	<1	Scarlet globemallow	8	<1
			Milkvetch	5	<1
			Senecio spp.	1	<1
Browse			Browse		
Big sagebrush	471	16	Big sagebrush	69	3
			Shadscale saltbush	46	1
			Douglas rabbitbrush	32	<1
			Winterfat	20	1
			Snakeweed	17	1
			Horsebrush	14	<1

Table 13. Biomass and canopy cover by species for the polwed natural recovery zones at the sagebrush location. Data collected on August 30, 1974.

Level Slope			West Slope		
Species	Kg/hec	% Cover	Species	Kg/hec	% Cover
Grasses			Grasses		
Indian ricegrass	252	14	Indian ricegrass	105	4
Western wheatgrass	189	9	Needle-and-thread	32	1
Needle-and-thread	160	9	Western wheatgrass	3	<1
Squirreltail bottlebrush	1	<1			
Forbs			Forbs		
Scarlet globemallow	72	8	White gilia	194	6
Russian thistle	60	4	Buckwheat	68	2
Phlox	42	1	Cryptantha	63	4
White gilia	21	<1	Double bladderpod	43	2
Cryptantha	14	1	Milkvetch	36	2
Hairy goldenaster	5	<1	False yarrow	29	1
Groundsmoke	5	1	Hairy goldenaster	17	1
Buckwheat	1	<1	Scarlet globemallow	5	<1
Milkvetch	1	<1	Phlox	5	<1
Browse			Browse		
none			Winterfat	63	3
			Broom snakeweed	39	1
			Horsebrush	1	<1

Table 14. Biomass and canopy cover by species for the scraped natural recovery zones at the sagebrush location.

Data collected on August 29, 1974

Level Slope			West Slope		
Species	Kg/hec	% Cover	Species	Kg/hec	% Cover
Grasses			Grasses		
Needle-and-thread	131	6	Western wheatgrass	82	4
Western wheatgrass	102	5	Indian ricegrass	77	3
Indian ricegrass	98	3	Needle-and-thread	16	1
Poa spp.	33	1	Blue grama	10	<1
Cheatgrass	1	<1	Cheatgrass	1	<1
Forbs			Forbs		
Phlox	141	5	White gilia	215	10
Scarlet globemallow	110	10	Buckwheat	80	3
Hairy goldenaster	47	2	Scarlet globemallow	19	1
White gilia	49	2	Hairy goldenaster	17	1
Buckwheat	21	1	Cryptantha	14	1
Double bladderpod	21	1	Wild pea	14	<1
False yarrow	13	<1	Phlox	13	<1
Wild pea	7	<1	Hood phlox	7	<1
Lichen	1	<1	Double bladderpod	5	<1
			False yarrow	2	<1
			Lambsquarters	1	<1
Browse			Lichen	1	<1
Broom snakeweed	7	<1			
			Browse		
			Douglas rabbitbrush	46	1
			Horsebrush	7	<1
			Shadscale saltbrush	6	<1
			Broom snakeweed	1	<1

Table 15. Biomass and canopy cover by species for the native control zones at the low elevation pinyon-juniper location. Data collected on August 27, 1973.

North Slope			Ridge Top			South Slope		
Species	Kg/hec	% Cover	Species	Kg/hec	% Cover	Species	Kg/hec	% Cover
Grasses			Grasses			Grasses		
Indian ricegrass	28	3	Western wheatgrass	6	1	Western wheatgrass	43	2
Western wheatgrass	17	2	Indian ricegrass	4	1	Indian ricegrass	11	2
Forbs			Forbs			Forbs		
Phlox	131	2	Rock aster	197	6	Phlox	94	1
Goldenweed	54	2	Phlox	98	1	Goldenweed	30	1
Rock aster	45	3	Goldenweed	33	1	Rock Aster	28	2
Aster spp.	27	3	Evening primrose	15	1	Smallflower aster	27	1
Evening primrose	21	3	Aster spp.	5	<1	Evening primrose	20	2
White buckwheat	10	1	White buckwheat	4	<1	White buckwheat	11	1
Lewis flax	2	<1	Smallflower aster	1	<1	Dandelion	5	<1
Double bladderpod	2	<1	Double bladderpod	1	<1	Lewis flax	1	<1
Browse			Browse			Browse		
Pinyon pine	87	11	Pinyon pine	42	8	Pinyon pine	55	5
Broom snakeweed	45	1	Mountain mahogany	37	4	Mountain mahogany	19	2
Serviceberry	35	3	Winterfat	30	2	Utah juniper	19	3
Mountain mahogany	23	2	Utah juniper	7	1	Winterfat	17	2
Winterfat	22	1	Broom snakeweed	5	<1	Broom snakeweed	11	1
			Serviceberry	3	<1			
			Snowberry	1	<1			

Table 16. Biomass and canopy cover by species for the plowed natural recovery zones at the low elevation pinyon-juniper location. Data collected on August 27, 1973.

North Slope			Ridge Top			South Slope		
Species	Kg/hec	% Cover	Species	Kg/hec	% Cover	Species	Kg/hec	% Cover
Grasses			Grasses			Grasses		
Indian ricegrass	13	1	Indian ricegrass	15	2	Indian ricegrass	18	3
Western wheatgrass	1	<1	Western wheatgrass	2	<1	Western wheatgrass	1	4
Forbs			Forbs			Forbs		
Lewis flax	37	3	Phlox	32	<1	Mint	60	3
White buckwheat	36	2	Rock aster	26	1	Cryptantha	14	<1
Phlox	18	1	White buckwheat	22	1	Goldenweed	8	<1
Goldenweed	17	1	Goldenweed	19	1	White buckwheat	8	1
Mint	11	1	Evening primrose	18	1	Lambsquarters	5	< 1
Double bladderpod	8	<1	Lewis flax	15	1	Bull thistle	3	< 1
Rock aster	8	<1	Double bladderpod	12	1	Dandelion	3	< 1
Evening primrose	5	<1	Mint	12	1	Lewis flax	3	< 1
Aster spp.	2	<1	Aster spp.	2	<1	Aster spp.	2	< 1
			Smallflower aster	2	<1	Rock aster	2	< 1
						Phlox	2	< 1
						Double bladderpod	2	< 1
						Small flower aster	1	< 1
Browse			Browse			Browse		
none			Winterfat	32	1	none		
			Serviceberry	5	<1			

Table 17. Biomass and canopy cover by species for the scraped natural recovery zones at the low elevation pinyon-juniper location. Data collected on August 27, 1973.

North Slope			Ridge Top			South Slope		
Species	Kg/hec	% Cover	Species	Kg/hec	% Cover	Species	Kg/hec	% Cover
Indian ricegrass	11	1	Western wheatgrass	42	3	Indian ricegrass	56	4
Western wheatgrass	7	1	Indian ricegrass	24	2	Western wheatgrass	4	1
Forbs			Forbs			Forbs		
Goldenweed	50	2	Russian thistle	97	3	Bull thistle	45	1
Evening primrose	20	1	Evening primrose	60	1	Double bladderpod	25	1
Rock aster	14	<1	Phlox	58	2	Mint	21	2
Double bladderpod	8	<1	Double bladderpod	45	1	Goldenweed	19	1
Lewis flax	6	1	Rock aster	40	1	Russian thistle	19	<1
Smallflower aster	4	<1	Goldenweed	34	1	Yellow salsify	14	<1
Phlox	4	<1	Mint	23	1	White buckwheat	8	<1
Mint	3	<1	Lewis flax	11	1	Rock aster	5	<1
White buckwheat	3	<1	White buckwheat	7	<1	Smallflower aster	4	<1
			Aster spp.	3	<1	Dandelion	4	<1
			Scarlet globemallow	3	<1	Evening primrose	1	<1
						Lambsquarters	1	<1
Browse			Browse			Browse		
Broom snakeweed	40	3	none			Serviceberry	12	<1
Mountain mahogany	6	<1				Mountain Mahogany	8	<1

Table 18. Biomass and canopy cover by species for the native control zones at the low elevation pinyon-juniper location. Data collected on July 9, 1974.

North Slope			Ridge Top			South Slope		
Species	Kg/hec	% Cover	Species	Kg/hec	% Cover	Species	Kg/hec	% Cover
Grasses			Grasses			Grasses		
Western wheatgrass	52	2	Indian ricegrass	37	2	Western wheatgrass	94	3
Indian ricegrass	35	1	Western wheatgrass	25	1	Indian ricegrass	67	2
Forbs			Forbs			Forbs		
Rock aster	138	3	Rock Aster	102	4	Phlox	100	2
Phlox	90	2	Phlox	90	3	Goldenweed	86	3
Goldenweed	84	4	Goldenweed	89	2	False yarrow	31	1
Lewis flax	17	1	Double bladderpod	16	1	Rock aster	13	1
Evening primrose	7	<1	Cryptantha	6	<1	Mint	12	1
False yarrow	5	<1	Lewis flax	6	<1	Dandelion	2	<1
Double bladderpod	4	<1	Lambsquarters	3	<1	Double bladderpod	2	<1
Lambsquarters	2	<1	Mint	1	<1			
Browse			Browse			Browse		
Mountain mahogany	88	1	Pinyon pine	82	5	Pinyon pine	52	4
Pinyon pine	57	6	Big sagebrush	36	1	Mountain mahogany	33	3
Serviceberry	10	1	Snowberry	24	<1	Douglas rabbitbrush	5	<1
Douglas rabbitbrush	3	<1	Utah juniper	23	1	Winterfat	2	<1
			Serviceberry	20	1			
			Mountain mahogany	5	<1			
			Horsebrush	2	<1			

Table 19. Biomass and canopy cover by species for the plowed natural recovery zones at the low elevation pinyon-juniper location. Data collected on July 5, 1974.

North Slope			Ridge Top			South Slope		
Species	Kg/hec	% cover	Species	Kg/hec	%cover	Species	Kg/hec	%cover
<u>Grasses</u>			<u>Grasses</u>			<u>Grasses</u>		
Indian ricegrass	50	2	Indian ricegrass	62	3	Indian ricegrass	78	2
Western wheatgrass	9	<1	Needle-and-thread	7	<1	Western wheatgrass	13	<1
			Western wheatgrass	2	<1			
<u>Forbs</u>			<u>Forbs</u>			<u>Forbs</u>		
Cryptantha	64	2	Lewis flax	76	2	Mint	45	4
Goldenweed	44	1	Cryptantha	62	2	Cryptantha	42	1
Mint	19	1	White gilia	52	2	Phlox	30	1
Lewis flax	15	1	Double bladderpod	43	1	Goldenweed	22	1
Phlox	14	1	Mint	37	1	Lewis flax	6	<1
White gilia	10	<1	Goldenweed	36	1	Double bladderpod	4	<1
Evening primrose	7	1	Phlox	19	<1			
Rock aster	3	<1	Rock aster	18	<1			
Lambsquarters	2	<1	Lambsquarters	6	<1			
			Senecio spp.	3	<1			
<u>Browse</u>			<u>Browse</u>			<u>Browse</u>		
Douglas rabbitbrush	23	2	Horsebrush	7	<1	Horsebrush	14	<1
Horsebrush	1	<1	Douglas rabbitbrush	3	<1			

Table 20. Biomass and canopy cover by species for the scraped natural recovery zones at the low elevation pinyon-juniper location. Data collected on July 8, 1974.

North Slope			Ridge Top			South Slope		
Species	Kg/hec	% cover	Species	Kg/hec	% cover	Species	Kg/hec	% cover
Grasses			Grasses			Grasses		
Indian ricegrass	92	3	Western wheatgrass	78	2	Indian ricegrass	82	3
Western wheatgrass	29	1	Indian ricegrass	38	1	Western wheatgrass	15	1
Forbs			Forbs			Forbs		
Cryptantha	66	2	Lewis flax	86	5	Cryptantha	86	2
Goldenweed	57	3	White gilia	44	2	Mint	80	3
Lewis flax	55	2	Double bladderpod	43	1	Double bladderpod	35	1
Mint	42	1	Phlox	40	2	Goldenweed	22	<1
Rock aster	23	<1	Cryptantha	29	<1	Phlox	19	<1
Phlox	20	1	Mint	27	1	Daisy	11	<1
White gilia	13	1	Goldenweed	24	2	Western wallflower	6	<1
Squaw apple	12	1	Rock aster	20	<1	False yarrow	4	<1
False yarrow	11	<1	Lambsquarters	2	<1	Lambsquarters	2	<1
Evening primrose	5	<1	Scarlet globemallow	1	<1			
Lambsquarters	2	<1						
Browse			Browse			Browse		
Douglas rabbitbrush	47	3	Douglas rabbitbrush	38	1	Horsebrush	12	1
Horsebrush	4	<1	Mountain mahogany	12	<1			
			Horsebrush	2	<1			

Table 21. Biomass and canopy cover by species for the native control zones at the low elevation pinyon-juniper location. Data collected on September 4, 1974.

North Slope			Ridge Top			South Slope		
Species	Kg/hec	% cover	Species	Kg/hec	% cover	Species	Kg/hec	% cover
Grasses			Grasses			Grasses		
Western wheatgrass	53	2	Indian ricegrass	45	2	Western wheatgrass	75	2
Indian ricegrass	30	1	Western wheatgrass	45	1	Indian ricegrass	29	1
			Poa spp.	1	<1			
Forbs			Forbs			Forbs		
Rock aster	124	3	Rock aster	158	3	Phlox	112	2
Goldenweed	87	4	Phlox	64	2	Rock aster	43	<1
Phlox	87	2	Lewis flax	40	1	Goldenweed	40	1
Lewis flax	22	1	Goldenweed	23	1	Mint	24	1
Buckwheat	14	<1	Double bladderpod	16	<1	Daisy	3	<1
Dougle bladderpod	3	<1	Cryptantha	4	<1	Aster spp.	1	<1
Aster spp.	2	<1	Daisy	1	<1	False yarrow	1	<1
White gilia	2	<1	Mustard	1	<1	Lewis flax	1	<1
Daisy	1	<1				Mustard	1	<1
Browse			Browse			Browse		
Mountain mahogany	95	3	Serviceberry	176	7	Utah juniper	106	3
Broom snakeweed	40	2	Mountain mahogany	67	3	Mountain mahogany	67	3
Pinyon pine	31	<1	Winterfat	21	1	Broom snakeweed	57	2
Winterfat	15	<1	Broom snakeweed	20	1			

Table 22. Biomass and canopy cover by species for the plowed natural recovery zones at the low elevation pinyon-juniper location. Data collected on September 3, 1974.

North Slope			Ridge Top			South Slope		
Species	Kg/hec	% cover	Species	Kg/hec	% cover	Species	Kg/hec	% cover
Grasses			Grasses			Grasses		
Indian ricegrass	47	2	Indian ricegrass	61	3	Indian ricegrass	122	4
Western wheatgrass	23	1	Needle-and-thread	9	<1	Western wheatgrass	1	<1
Needle-and-thread	1	<1	Western wheatgrass	5	<1			
Forbs			Forbs			Forbs		
Cryptantha	92	3	Lewis flax	91	4	Mint	105	5
Goldenweed	47	1	White gilia	59	2	Cryptantha	61	1
Lewis flax	17	1	Cryptantha	56	2	Goldenweed	27	<1
Double bladderpod	14	<1	Double bladderpod	46	1	Phlox	13	<1
Phlox	13	1	Mint	41	1	Mustard	3	<1
White gilia	11	<1	Goldenweed	37	1	Lewis flax	2	<1
Lambsquarters	1	<1	Phlox	17	<1	Lambsquarters	2	<1
Mustard	1	<1	False yarrow	15	<1	Senecio spp.	2	<1
			Rock aster	15	<1	Double bladderpod	1	<1
			Russian thistle	9	<1	Russian thistle	1	<1
			Lambsquarters	4	<1			
			Senecio spp.	1	<1			
Browse			Browse			Browse		
Douglas rabbitbrush	22	1	Douglas rabbitbrush	61	2	Broom snakeweed	7	<1
						Douglas rabbitbrush	2	<1

Table 23. Biomass and canopy cover by species for the scraped natural recovery zones at the low elevation pinyon-juniper location. Data collected on September 3, 1974.

North Slope			Ridge Top			South Slope		
Species	Kg/hec	% cover	Species	Kg/hec	% cover	Species	Kg/hec	% cover
Grasses			Grasses			Grasses		
Indian ricegrass	75	2	Western wheatgrass	72	2	Indian ricegrass	67	2
Western wheatgrass	25	1	Indian ricegrass	42	1	Western wheatgrass	43	2
			Needle-and-thread	2	<1			
Forbs			Forbs			Forbs		
Cryptantha	54	2	Lewis flax	55	2	Mint	83	3
Phlox	33	2	White gilia	51	2	Cryptantha	41	1
Lewis flax	25	1	Phlox	40	2	Goldenweed	27	1
Rock aster	24	<1	Goldenweed	32	2	Phlox	14	1
Goldenweed	18	1	Double bladderpod	19	<1	White gilia	5	<1
Double bladderpod	17	<1	Cryptantha	18	<1	False yarrow	3	<1
White gilia	12	<1	Rock aster	18	<1	Rock aster	3	<1
Daisy	1	<1	False yarrow	1	<1	Lambsquarters	2	<1
Lambsquarters	1	<1	Mint	1	<1	Daisy	1	<1
Mint	1	<1	Mustard	1	<1	Mustard	1	<1
Oregon grape	1	<1	Scarlet globemallow	1	<1			
Browse			Browse			Browse		
Douglas rabbitbrush	54	3	Douglas rabbitbrush	66	2	Mountain mahogany	48	1
Mountain mahogany	15	<1	Winterfat	6	<1	Douglas rabbitbrush	2	<1

Table 24. Biomass and canopy cover by species for the native control zones at the high elevation pinyon-juniper location. Data collected on August 30, 1974.

Northwest Slope			South Slope		
Species	Kg/hec	% Cover	Species	Kg/hec	% Cover
Grasses			Grasses		
Western wheatgrass	214	12	Indian ricegrass	125	5
Indian ricegrass	193	4	Squirreltail bottlebrush	100	1
Junegrass	75	4	Beardless wheatgrass	60	3
Sheep fescue	68	3	Western wheatgrass	57	5
Squirreltail bottlebrush	34	1	Cheatgrass	53	7
Crested wheatgrass	17	1	Sheep fescue	20	1
Cheatgrass	12	1	Foxtail barley	15	1
			Junegrass	2	<1
Forbs			Forbs		
False yarrow	44	2	Aster spp.	97	4
Goldenweed	34	4	Lambsquarters	52	3
Aster spp.	32	1	False yarrow	31	1
Scarlet globemallow	19	1	Mustard	24	4
Phlox	17	1	Double bladderpod	7	2
Hawksbeard	14	1	Stickseed	6	2
Dandelion	4	<1	Buckwheat	3	<1
Double bladderpod	3	<1	Dandelion	1	<1
Buckwheat	1	<1			
Browse			Browse		
Antelope bitterbrush	80	8	Antelope Bitterbrush	39	3
Pinyon-pine	59	<1	Big sagebrush	34	3
Big rabbitbrush	45	3	Mountain mahogany	20	1
Snowberry	32	3	Snowberry	16	<1
Broom snakeweed	12	1	Pinyon-pine	2	<1

Table 25. Biomass and canopy cover by species for the plowed natural recovery zones at the high elevation pinyon-juniper location. Data collected on August 30, 1973.

Northwest Slope			South Slope		
Species	Kg/hec	% Cover	Species	Kg/hec	% Cover
Grasses			Grasses		
Indian ricegrass	123	8	Indian ricegrass	211	14
Western wheatgrass	50	2	Cheatgrass	68	4
Squirreltail bottlebrush	17	1	Western wheatgrass	8	<1
Cheatgrass	12	1	Squirreltail bottlebrush	3	<1
Beardless wheatgrass	8	<1	Beardless wheatgrass	2	<1
Forbs			Forbs		
Lambsquarters	59	3	False yarrow	58	3
Scarlet globemallow	43	1	Lambsquarters	44	1
Aster spp.	38	1	Stickseed	38	2
False yarrow	29	1	Aster spp.	28	1
Stickseed	23	3	Mustard	18	2
Double bladderpod	13	<1	Buckwheat	18	<1
Dandelion	12	1	Double bladderpod	7	<1
Buckwheat	10	<1	Phlox	2	<1
Red trumpet flower	6	<1			
Browse			Browse		
none			none		

Table 26. Biomass and canopy cover by species for the scraped natural recovery zones at the high elevation pinyon-juniper location. Data collected on August 30, 1973.

Northwest Slope			South Slope		
Species	Kg/hec	% Cover	Species	Kg/hec	% Cover
Grasses			Grasses		
Western wheatgrass	165	8	Indian ricegrass	235	16
Indian ricegrass	92	5	Cheatgrass	27	2
Cheatgrass	62	2	Beardless wheatgrass	19	1
Beardless wheatgrass	49	3	Western wheatgrass	8	1
			Foxtail barley	2	<1
Forbs			Forbs		
Aster spp.	72	3	Aster spp.	73	3
Lambsquarters	40	1	Mustard	33	1
False yarrow	26	1	Double bladderpod	21	1
Double bladderpod	20	1	Lambsquarters	16	<1
Dandelion	10	1	Buckwheat	10	<1
Red trumpet flower	7	<1	Stickseed	9	<1
Buckwheat	3	<1	False yarrow	4	<1
Mustard	2	<1	Arrowleaf balsamroot	1	<1
Hawksbeard	1	<1			
Browse			Browse		
none			none		

Table 27. Biomass and canopy cover by species for the native control zones at the high elevation pinyon-juniper location. Data collected on June 22, 1974.

Northwest Slope			South Slope		
Species	Kg/hec	% Cover	Species	Kg/hec	% Cover
Grasses			Grasses		
Indian ricegrass	230	9	Indian ricegrass	199	8
Western Wheatgrass	189	11	Western wheatgrass	134	7
Junegrass	60	3	Squirreltail bottlebrush	80	5
Squirreltail bottlebrush	18	1	Cheatgrass	40	2
Cheatgrass	7	<1	Junegrass	29	1
Needle-and-thread	7	<1			
Forbs			Forbs		
Phlox	79	1	False yarrow	54	1
Dandelion	27	1	Double bladderpod	37	1
False yarrow	17	1	Rose pussytoes	6	1
Senecio spp.	9	<1	Senecio spp.	6	<1
Rose pussytoes	5	1	Western wallflower	2	<1
Arrowleaf balsamroot	5	<1			
Scarlet globemallow	4	<1			
Hairy golden aster	3	<1			
Browse			Browse		
Snowberry	91	2	Antelope bitterbrush	29	1
Antelope Bitterbrush	79	7	Mountain mahogany	21	1
Big rabbitbrush	47	3	Snowberry	15	1
Shadscale saltbush	6	1	Shadescale saltbrush	2	<1

Table 28. Biomass and canopy cover by species for the plowed natural recovery zones at the high elevation pinyon-juniper location. Data collected on June 22, 1974.

Northwest Slope			South Slope		
Species	Kg/hec	% Cover	Species	Kg/hec	% Cover
Grasses			Grasses		
Indian ricegrass	311	14	Indian ricegrass	380	15
Western wheatgrass	85	6	Cheatgrass	76	5
Cheatgrass	50	3	Squirreltail bottlebrush	23	1
Squirreltail bottlebrush	28	1	Western wheatgrass	6	<1
Forbs			Forbs		
False yarrow	57	2	False yarrow	83	3
Double bladderpod	36	1	Red trumpet flower	21	<1
Red trumpet flower	10	1	Double bladderpod	16	<1
Senecio spp.	9	<1	Cryptantha	8	<1
Dandelion	2	<1			
Phlox	2	<1			
Browse			Browse		
Snowberry	8	<1	none		
Antelope bitterbrush	6	<1			
Big rabbitbrush	4	<1			

Table 29. Biomass and canopy cover by species for the scraped natural recovery zones at the high elevation pinyon-juniper location. Data collected on June 21, 1974

Northwest Slope			South Slope		
Species	Kg/hec	% Cover	Species	Kg/hec	% Cover
Grasses			Grasses		
Indian ricegrass	312	8	Indian ricegrass	338	17
Western wheatgrass	116	6	Cheatgrass	18	1
Squirreltail bottlebrush	46	1	Squirreltail bottlebrush	18	1
Cheatgrass	15	1	Needle-and-thread	17	<1
			Western wheatgrass	2	<1
Forbs			Forbs		
False yarrow	145	3	False yarrow	43	1
Cryptantha	60	<1	Arrowleaf balsamroot	15	1
Senecio spp.	39	1	Double bladderpod	11	<1
Double bladderpod	36	1	Cryptantha	5	<1
Rocky Mountain penstemon	1	<1	Hairy golden aster	4	<1
			Phlox	3	<1
			Milkvetch	3	<1
Browse					
Snowberry	14	<1			
Horsebrush	11	<1	Browse		
			none		

Table 30. Biomass and canopy cover by species for the native control zones at the high elevation pinyon-juniper location. Data collected on August 28, 1974.

Northwest Slope			South Slope		
Species	Kg/hec	% Cover	Species	Kg/hec	% Cover
Grasses			Grasses		
Western wheatgrass	240	9	Indian ricegrass	267	11
Indian ricegrass	232	9	Western wheatgrass	152	6
Junegrass	63	3	Cheatgrass	94	4
Beardless wheatgrass	47	2	Squirreltail bottlebrush	82	5
Squirreltail bottlebrush	24	1	Beardless wheatgrass	1	<1
Forbs			Forbs		
Phlox	106	2	Double bladderpod	41	1
Double bladderpod	36	2	False yarrow	27	1
False yarrow	21	1	Goldenweed	8	<1
Scarlet globemallow	19	1	Cryptantha	5	<1
Cryptantha	17	1	Daisy fleabane	2	<1
Senecio spp.	11	1			
Red trumpet flower	2	<1			
Daisy fleabane	1	<1			
Hairy golden aster	1	<1			
Browse			Browse		
Antelope bitterbrush	121	8	Antelope bitterbrush	41	1
Prickly pear cactus	3	<1	Big sagebrush	19	1
			Broom snakeweed	13	1
			Snowberry	3	<1

Table 31. Biomass and canopy cover by species for the plowed natural recovery zones at the high elevation pinyon-juniper location. Data collected on August 27, 1974.

Northwest Slope			South Slope		
Species	Kg/hec	% Cover	Species	Kg/hec	% Cover
Grasses			Grasses		
Indian ricegrass	380	13	Indian ricegrass	610	17
Western wheatgrass	170	6	Cheatgrass	38	2
Cheatgrass	45	1	Squirreltail bottlebrush	7	<1
Big bluegrass	34	<1			
Squirreltail bottlebrush	20	<1			
Beardless wheatgrass	1	<1	Forbs		
			False yarrow	30	1
Forbs			Double bladderpod	14	<1
Daisy fleabane	82	2	Daisy fleabane	5	<1
Double bladderpod	42	2	Cryptantha	2	<1
False yarrow	19	1			
Red trumpet flower	6	<1			
Lambsquarters	2	<1	Browse		
Aster spp.	1	<1	none		
Cryptantha	1	<1			
Senecio spp.	1	<1			
Browse					
none					

Table 32. Biomass and canopy cover by species for the scraped natural recovery zones at the high elevation pinyon-juniper location. Data collected on August 27, 1974.

Northwest Slope			South Slope		
Species	Kg/hec	% Cover	Species	Kg/hec	% Cover
Grasses			Grasses		
Indian ricegrass	379	12	Indian ricegrass	503	13
Western wheatgrass	81	3	Squirreltail bottlebrush	40	1
Squirreltail bottlebrush	47	1	Beardless wheatgrass	34	1
Beardless wheatgrass	15	1	Western wheatgrass	9	1
Cheatgrass	11	<1	Cheatgrass	9	<1
Poa spp.	1	<1	Poa spp.	1	<1
Forbs			Forbs		
False yarrow	121	3	Arrowleaf balsamroot	15	1
Daisy fleabane	68	2	Daisy fleabane	15	<1
Phlox	31	<1	Double bladderpod	12	<1
Cryptantha	18	1	Cryptantha	9	<1
Double bladderpod	10	<1	False yarrow	1	<1
Senecio spp.	9	<1	Phlox	1	<1
Red trumpet flower	6	<1			
Browse			Browse		
Winterfat	38	<1	none		
Big rabbitbrush	3	<1			

Table 33. Biomass and canopy cover by species for the native control zones at the mountain browse location. Data collected on August 31, 1973.

Gentle Northwest Slope			Steeper Northwest Slope		
Species	Kg/hec	% Cover	Species	Kg/hec	% Cover
Grasses			Grasses		
Western wheatgrass	46	<1	Junegrass	73	<1
Junegrass	21	<1	Mountain brome	11	<1
Mountain brome	14	1	Western wheatgrass	9	1
Sheep fescue	10	<1	Festuca spp.	3	2
Forbs			Forbs		
Lupine	157	7	Sulphur buckwheat	73	2
Phlox	103	4	Evening primrose	61	3
Sulphur buckwheat	88	7	Phlox	61	3
Arrowleaf balsamroot	49	1	Lupine	49	2
Rocky Mountain penstemon	27	1	White buckwheat	44	1
Wild pea	16	2	Rocky Mountain penstemon	27	1
White buckwheat	15	<1	Indian paintbrush	24	1
Evening primrose	3	<1	Scarlet globemallow	12	1
Lambsquarters	2	<1	Wild pea	12	1
Dandelion	2	<1	Loco	9	1
			Arrowleaf balsamroot	3	1
			Nodding onion	3	<1
Browse			Browse		
Big sagebrush	888	14	Big sagebrush	448	18
Snowberry	585	8	Antelope bitterbrush	270	10
Serviceberry	476	20	Serviceberry	261	<1
Antelope bitterbrush	290	7	Douglas rabbitbrush	100	3
Broom snakeweed	109	3	Snowberry	71	8
			Broom snakeweed	39	1
			Horsebrush	9	2

Table 34. Biomass and canopy cover by species for the plowed natural recovery zones at the mountain browse location. Data collected on August 31, 1973.

Gentle Northwest Slope

Species	Kg/hec	% Cover
Grasses		
Junegrass	12	<1
Western wheatgrass	8	<1
Mountain brome	3	<1
Forbs		
Lupine	283	6
Lambsquarters	203	2
Arrowleaf balsamroot	146	4
Wild pea	79	3
Eriogonum spp.	44	<1
Groundsmoke	27	2
Astragalus spp.	9	<1
Evening primrose	6	<1
Hawksbeard	2	<1
Browse		
Douglas rabbitbrush	124	2
Snowberry	61	1
Big sagebrush	23	<1
Serviceberry	9	<1

Steeper Northwest Slope

Species	Kg/hec	% Cover
Grasses		
none		
Forbs		
Lambsquarters	494	7
Lupine	483	6
Wild pea	138	2
Scarlet globemallow	33	1
Evening primrose	24	1
Lewis flax	20	<1
Astragalus spp.	18	<1
Eriogenum spp.	11	1
Phlox	3	<1
Browse		
Douglas rabbitbrush	130	2
Serviceberry	103	2
Big sagebrush	55	<1
Antelope bitterbrush	46	1
Snowberry	23	<1
Horsebrush	12	<1

Table 35. Biomass and canopy cover by species for the scraped natural recovery zones at the mountain browse location. Data collected on August 31, 1973.

Gentle northwest slope

Species	Kg/hec	% Cover
<u>Grasses</u>		
Western wheatgrass	27	1
<u>Forbs</u>		
Lupine	174	3
Lambsquarters	107	1
Eriogonum spp.	53	1
Arrowleaf blasamroot	36	1
Wild pea	29	2
Phlox	8	<1
Nodding onion	6	<1
Evening primrose	5	<1
Hawksbeard	5	<1
Groundsmoke	3	<1
<u>Browse</u>		
Snowberry	97	4
Douglas rabbitbrush	88	2
Big sagebrush	70	1
Antelope bitterbrush	30	<1
Serviceberry	20	<1

Steeper Northwest Slope

Species	kg/hec	% Cover
<u>Grasses</u>		
Mountain brome	21	1
Western wheatgrass	12	1
<u>Forbs</u>		
Lambsquarters	397	8
Lupine	202	6
Phlox	36	1
Evening primrose	27	1
Wild pea	21	1
Aster spp.	18	<1
Arrowleaf balsamroot	15	<1
Indian paintbrush	15	<1
Rocky Mountain penstemon	14	<1
Hawksbeard	11	<1
Scarlet globemallow	6	<1
<u>Browse</u>		
Serviceberry	88	3
Antelope	61	1
Douglas rabbitbrush	61	1
Big sagebrush	61	<1
Horsebrush	39	1
Snowberry	33	1
Broom snakeweed	24	<1

Table 36. Biomass and canopy cover by species for the native control zones at the mountain browse location. Data collected on June 25, 1974.

Gentle Northwest Slope			Steeper Northwest Slope		
Species	Kg/hec	% Cover	Species	Kg/hec	% Cover
<u>Grasses</u>			<u>Grasses</u>		
Bib bluegrass	64	4	Big bluegrass	93	7
Mountain brome	34	1	Indian ricegrass	16	1
Western Wheatgrass	27	1	Western wheatgrass	7	4
<u>Forbs</u>			<u>Forbs</u>		
Lupine	57	3	Phlox	81	7
Wild pea	53	3	Rocky Mountain Penstemon	27	2
Sulphur buckwheat	46	2	Lupine	22	2
SEnecio spp.	17	1	Arrowleaf balsamroot	22	1
Phlox	16	1	Loco	21	1
Spreading daisy	15	1	Spreading daisy	20	1
Indian paintbrush	12	<1	Senecio spp.	16	1
Loco	9	<1	Indian paintbrush	15	<1
Arrowleaf Balsamroot	7	<1	Lambsquarters	12	1
Lambsquarters	6	<1	Wild pea	7	<1
Rocky Mountain penstemon	2	<1	Milkvetch	4	<1
			Aster spp.	3	<1
			Sulphur buckwheat	3	<1
<u>Browse</u>			<u>Browse</u>		
Serviceberry	1389	40	Antelope bitterbrush	591	14
Big sagebrush	353	14	Serviceberry	379	8
Snowberry	141	6	Big sagebrush	345	12
Antelope bitterbrush	112	3	Snowberry	84	2
Douglas rabbitbrush	27	1	Douglas rabbitbrush	46	1

Table 37. Biomass and canopy cover by species for the plowed natural recovery zones at the mountain browse location. Data collected on June 24, 1974.

Gentle Northwest Slope

Species	Kg/hec	% Cover
Grasses		
Western wheatgrass	49	3
Big bluegrass	7	<1
Cheatgrass	1	<1
Forbs		
Lupine	171	8
Wild pea	110	6
Euphorbia spp.	103	6
Senecio spp.	54	3
Arrowleaf balsamroot	34	2
Aster spp.	30	1
Groundsmoke	25	3
Lambsquarters	14	2
Eriogonum spp.	11	1
Loco	11	1
Rocky Mountain Penstemon	10	1
Milkvetch	2	<1
Western Wallflower	2	<1
Browse		
Douglas rabbitbrush	159	6
Snowberry	42	2
Serviceberry	13	<1
Big sagebrush	5	<1

Steeper Northwest Slope

Species	Kg/hec	% Cover
Grasses		
Western wheatgrass	41	<2
Big Bluegrass	7	<1
Needle-and-thread	20	1
Mountain brome	12	<1
Indian ricegrass	9	1
Forbs		
Lupine	251	6
Rocky Mountain penstemon	72	4
Wild pea	67	3
Groundsmoke	34	4
Euphorbia spp.	32	1
Senecio spp.	26	1
Spreading daisy	23	1
Milkvetch	22	2
Lambsquarters	20	2
Phlox	15	<1
Loco	10	1
Western wallflower	9	1
Dandelion	3	<1
Aster spp.	3	<1
Mustard	3	<1
Aster spp.	2	<1
Scarlet globemallow	2	<1
Eriogonum spp.	1	<1
Browse		
Douglas rabbitbrush	149	4
Serviceberry	60	2
Big sagebrush	22	<1
Snowberry	3	<1

Table 38. Biomass and canopy cover by species for the scraped natural recovery zones at the mountain browse location. Data Collected on June 24, 1974.

Gentle Northwest Slope

Species	Kg/hec	% Cover
Grasses		
Big bluegrass	56	3
Western wheatgrass	55	2
Mountain brome	8	<1
Squirreltail bottlebrush	8	<1
Needle-and-thread	8	<1
Forbs		
Lupine	228	9
Arrowleaf balsamroot	95	4
Wild pea	31	2
Senecio spp.	31	1
Euphorbia spp.	28	1
Aster spp.	26	1
Phlox	25	1
Rocky Mountain penstemon	20	1
Milkvetch	18	2
Western wallflower	12	<1
Scarlet globemallow	7	1
Eriogonum spp.	7	<1
Lambsquarters	6	1
Dandelion	5	1
Spreading daisy	5	<1
Groundsmoke	4	<1
Loco	3	<1
Browse		
Serviceberry	116	3
Antelope bitterbrush	64	1
Douglas rabbitbrush	60	2
Snowberry	16	1
Big Sagebrush	11	<1

Steeper Northwest Slope

Species	Kg/hec	% Cover
Grasses		
Western wheatgrass	35	2
Big bluegrass	31	2
Indian ricegrass	20	1
Needle-and-thread	11	1
Forbs		
Lupine	195	10
Wild pea	41	2
Lambsquarters	39	1
Euphorbia spp.	38	2
Milkvetch	29	2
Phlox	22	2
Eriogonum spp.	18	1
Aster spp.	16	<1
Senecio spp.	15	1
Scarlet globemallow	7	<1
Loco	6	1
Groundsmoke	5	<1
Nodding onion	4	<1
Dandelion	2	<1
False yarrow	2	<1
Rocky Mountain penstemon	2	<1
Western wallflower	2	<1
Lewis flax	1	<1
Mint	1	<1
Browse		
Snowberry	92	2
Serviceberry	69	1
Douglas rabbitbrush	33	1
Antelope bitterbrush	32	1
Big Sagebrush	19	<1
Horsebrush	3	<1

Table 39. Biomass and canopy cover by species for the native control zones at the mountain browse location. Data collected on August 26, 1974.

Gentle Northwest Slope

Species	Kg/hec	% Cover
Grasses		
Big bluegrass	79	4
Western wheatgrass	28	1
Forbs		
Sulpher buckwheat	90	3
Lupine	74	3
Wild pea	61	3
Arrowleaf balsamroot	25	2
Hood phlox	17	1
Spreading daisy	13	1
Rocky Mountain penstemon	10	<1
Lambsquarters	3	<1
Browse		
Serviceberry	1548	42
Big sagebrush	480	16
Antelope bitterbrush	167	4
Snowberry	123	5
Douglas rabbitbrush	23	1

Steeper Northwest Slope

Species	Kg/hec	% Cover
Grasses		
Big bluegrass	86	6
Needle-and-thread	13	1
Western wheatgrass	12	1
Indian ricegrass	11	1
Forbs		
Hood phlox	94	7
Lupine	29	2
Arrowleaf balsamroot	27	2
Daisy	22	1
Milkvetch	20	1
Rocky Mountain penstemon	19	1
Sulphur buckwheat	15	1
Senecio spp.	14	1
Wild pea	12	<1
Lambsquarters	5	<1
Euphorbia spp.	2	<1
Browse		
Antelope bitterbrush	622	14
Big sagebrush	421	13
Serviceberry	293	7
Snowberry	91	2
Douglas rabbitbrush	57	2
Broom snakeweed	21	1

Table 40. Biomass and canopy cover by species for the plowed natural recovery zones at the mountain browse location. Data collected on August 21, 1974.

Gentle Northwest Slope

Species	Kg/hec	% Cover
<u>Grasses</u>		
Western wheatgrass	53	3
Indian ricegrass	15	1
Big bluegrass	10	1
Needle-and-thread	1	<1
<u>Forbs</u>		
Lupine	193	9
Wild pea	118	7
Euphorbia spp.	97	5
Senecio spp.	53	3
Arrowleaf balsamroot	50	2
Groundsmoke	44	3
Rocky Mountain penstemon	31	2
Lambsquarters	28	2
Sulphur	9	1
Daisy	2	<1
Scarlet globemallow	2	<1
False yarrow	1	<1
Indian paintbrush	1	<1
Western wallflower	1	<1
<u>Browse</u>		
Douglas rabbitbrush	188	6
Serviceberry	21	<1
Big sagebrush	3	<1

Steeper Northwest Slope

Species	Kg/hec	% Cover
<u>Grasses</u>		
Western wheatgrass	43	2
Big bluegrass	22	1
Junegrass	5	<1
Needle-and-thread	5	<1
Indian ricegrass	4	<1
Squirreltail bottlebrush	1	<1
<u>Forbs</u>		
Lupine	282	7
Rocky Mountain penstemon	87	4
Groundsmoke	43	4
Wild pea	42	2
Euphorbia spp.	27	1
Senecio spp.	20	1
Lambsquarters	14	1
Western wallflower	11	1
Spreading daisy	7	<1
Scarlet globemallow	5	1
Loco	4	<1
<u>Browse</u>		
Douglas rabbitbrush	150	4
Serviceberry	67	2
Big sagebrush	19	<1
Snowberry	2	<1
Horsebrush	1	<1

Table 41. Biomass and canopy cover by species for the scraped natural recovery zones at the mountain browse location. Data collected on August 21, 1974.

Gentle Northwest Slope			Steeper Northwest Slope		
Species	Kg/hec	% Cover	Species	Kg/hec	% Cover
Grasses			Grasses		
Western wheatgrass	97	3	Western wheatgrass	37	2
Big bluegrass	49	3	Big bluegrass	31	2
Indian ricegrass	23	1	Indian ricegrass	19	1
Nodding brome	7	<1	Needle-and-thread	15	1
Needle-and-thread	6	<1			
			Forbs		
Forbs			Lupine Groundsmoke	201	10
Lupine	241	9	Euphorbia spp.	51	2
Arrowleaf balsamroot	101	5	Wild pea	47	2
Wild pea	37	2	Lambsquarters	44	2
Rocky Mountain penstemon	33	2	Hood phlox	42	2
Hood phlox	33	1	Sulphur buckwheat	23	2
Euphorbia spp.	32	1	Scarlet globemallow	15	1
Senecio spp.	29	1	Senecio spp.	14	1
Western wallflower	19	<1	Loco	9	1
Groundsmoke	17	2	Wild onion	4	1
Lambsquarters	14	1	Rocky Mountain penstemon	3	<1
Sulphur buckwheat	4	<1	Daisy	2	<1
Loco	3	<1		1	<1
Russian thistle	2	<1	Browse		
Spreading daisy	2	<1	Snowberry	116	3
Wild onion	2	<1	Serviceberry	53	1
			Douglas rabbitbrush	49	1
Browse			Antelope bitterbrush	41	1
Serviceberry	93	3	Big sagebrush	23	1
Douglas rabbitbrush	67	2	Horsebrush	19	1
Antelope bitterbrush	61	1	Broom snakeweed	12	<1
Snowberry	13	<1			
Big sagebrush	5	<1			
Horsebrush	2	<1			