VEGETATION AND SOIL WATER RESPONSE TO CONTOUR FURROWS, DOZER BASINS, AND SURFACE ADDITIONS OF TOPSOIL OR POWER PLANT ASH ON ARID COAL SPOILS[1]

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Abstract.--Two native shrubs and several native grasses were evaluated on two sodic coal spoils. The contour furrows and dozer basins produced the only significant establishment of plants in the study.

INTRODUCTION

Vegetation is hard to establish in the arid coal mining areas in northwest New Mexico, especially when spoils are saline and/or sodic, and low in organic matter. Topsoiling is not always a simple solution to the problem, as surface soils in the areas can have low moisture- and nutrient-holding capacities, and are commonly sodic (Scholl 1982; Gould 1982). Contour furrows and dozer basins can retain some runoff and increase soil water on steep slopes (Verma 1978; Aldon 1980; Jensen 1978). Combining surface shaping with surface amendments (mulching or surface incorporation) to reduce evaporation can improve establishment of vegetation on harsh sites (Scholl 1984). Power plant bottom ash, although inferior to topsoil as a surface amendment (Gould 1982) offers an alternative, because of low cost and availability.

This study was conducted to determine if plant establishment could be improved on coal mine spoil using surface shaping and/or amendments in areas with an annual precipitation of 15 cm. Additional objectives were to determine the amount and seasonal distribution of soil water resulting from the treatments, and if soil water levels are related to plant establishment.

METHODS

Study Site

The study was done at Navajo Mine in northwest New Mexico, near Farmington, at an elevation of approximately 1634 m. The annual precipitation averages 15 cm, divided about equally between summer and winter. Vegetation in unmined areas consists of desert grasses and shrubs, with low plant density (less than 10 plants m^{-2}). The most common soils are calcarious loamy sand to sandy loam in the A horizon, with varying levels of clay and $CaCO_3$ accumulation in the B horizon. They are developed from aeolian sands and vary in depth (Gould 1975).

The overburden typically consists of three geologic types; from the surface down, they are: 1) aeolian loamy sands, 2) brown (oxidized) shales, and 3) gray shales. Both shale beds may have thin (2 m) layers of soft sandstone or coal included (Scholl 1982). The overburden at the study site was approximately 25-40 m thick, with gray shale being the dominate type.

The graded spoil surface is undulating, with slopes between 5 and 30%. Both brown and gray shale spoil types are exposed in the study area. Chemical and physical properties of the two spoils and the topsoil and bottom ash amendment are shown in Table 1.

Two adjacent shale spoil areas (brown and gray) were contour furrowed. The areas were about 300 m apart on 4:1 east facing slopes. Furrowed and control plots (0.1ha, 3 reps. each) were laid out in alternating fashion. The top of each plot was located on contour near the top of the slope, with the plot extending down slope 40 m.

The dozer basin plots were laid out similarly on a nearby (30 m) west-facing gray shale slope.

The ash, topsoil, and control plots (3 reps. each treatment, 52 m^2) were laid out with the treatment replications together in rows to facilitate maneuvering of the equipment. These plots were on nearby level gray shale, about 40 m from the dozer basin plots.

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Treatments and Seeding

Furrows and Basins

A single disk plow (1.15 m diam. blade) mounted behind a crawler tractor was used to make the contour furrows (0.3 m deep, 0.6 m wide). The plow was operated on the contour, and furrows were interrupted every 5 m by lifting the plow. Center-to-center furrow spacing was 5 m.

Dozer basins were formed using a front-mounted dozer blade (2.4 m long) on the crawler tractor. Basins (0.3 m deep) were formed by pushing spoil (blade on contour) down-slope a distance of 5 m, then lifting the blade, leaving a contour depression and a berm. Pushing began at the bottom of the slope and the tractor backed uphill, creating a basin every 5 m. Basins were spaced along the contour as close to each other as possible, but the distance was varied to allow a straight push down-hill on convex or concave slopes.

Furrow, basin, and control plots were broadcast seeded (28 kg ha^{-1}) with the following species: fourwing saltbush (Atriplex canescens), shadscale saltbush (Atriplex confertifolia), alkali sacaton (Sporobolus airoides), sand dropseed (Sporobolus cryptandrus), galleta (Hilaria jamesii), Indian ricegrass (Oryzopsis hymenoides), and western wheatgrass (Agropyron smithii). All plots were then broadcast mulched with straw (2.2 Mg ha^{-1}).

Topsoil and bottom ash

Topsoil plots were covered with soil (0.15 m deep), drill seeded (20 kg ha^{-1}, above species), straw mulched (2.2 Mg ha^{-1}), and crimped. Topsoil was obtained from a nearby range site. Ash plots were covered with ash (0.07 m deep) and then disked (0.15 m deep) twice to incorpor- ate ash into the spoil. Ash and control plots were then drill seeded and mulched like the topsoil. All plot work was completed in November 1977.

Stand density (plant count by species m^{-2}) was determined along furrows in a band 1 m wide, and in dozer basins in the area where water collected (2.5 x 1.2 m). On control, ash, and topsoil plots, the whole area was counted. A composite of three disturbed soil samples (0-0.15 m depth) was taken on each plot in May, July, and October. Water content of the samples was determined by weighing before and after oven drying. A randomized analysis of variance with Duncan's multiple range test was used to compare treatments against controls.

RESULTS AND DISCUSSION

Stand density

Fourwing and, to a lesser extent, shadscale saltbush were the main plants to become established on furrow and basin plots (Table 2). Both appeared to become better established (not tested statistically) on brown spoil than on gray.

Furrow plots on both spoils had significantl better stands of both fourwing and shadscale saltbush than the controls. The dozer basin treatment showed no advantage over the control for fourwing saltbush, but shadscale did do better in basins. Some grasses emerged the spring following the fall seeding, but died out during the first summer. A few (1 m^{-2}) western wheatgrass plants had become established 2 years after seeding on the furrow and basin plots.

Although a number (1 m^{-1} of drill row) of fourwing and shadscale saltbushes emerged, the spring following seeding on ash and topsoil, none survived after 2 years. Likewise, a good stand (25 m^{-1}) of grasses was obtained the first spring, but the seedlings died during the summer. Some Indian ricegrass (5 m^{-2}) and annual saltbush (Atriplex powellii) volunteered, mainly on the topsoil plots in the second year.

Soil Water Content

Precipitation during the summer period of soil water measurement totaled 7.57 cm. During the five winter months prior to the study, a total of 7.47 cm was received. The majority (5.9 cm) of winter moisture was received in December and January as snow. Winter precipitation was stored much more efficiently than the summer rainfall in all treatments, as judged by comparing May and October soil water (Table 3). For the controls in gray shale spoil, however, May and October soil water levels were similar. The brown shale control plots had more water stored in May than later, but still less water than the furrows. Stored winter moisture persisted longest on furrowed brown shale; July water content remained higher than October.

The topsoil and ash plots, on the other hand, dried out rapidly by July. The topsoil an control plots showed some increase from late summer rains in October.

Vegetation and seasonal water relationship

The furrowing and basin treatments clearly favored the cool-season and clay-soil-adapted species (fourwing and shadscale saltbushes, western wheatgrass). The furrows and basins accumulated considerable snow over the winter (snow was deeper and persisted longer in furrows and by March some standing water was observed. Fourwing saltbush germinated in March, with plants developing just above the water line.

A useful approach to establishing the warm-season grasses would be to extend water storage in furrows well into the summer period. Combining furrows with treatments such as topso and organic amendments, applied in the fall pri to seeding, could prove a successful strategy.

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Table 1. Spoil and amendment properties* at Navajo Mine.

Analysis	Spoils: Brown Shale	Spoils: Gray Shale	Amendments: Topsoil	Amendments: bottom ash
SAR	28.4	32.5	9.5	2.2
EC (dS m^{-1})	8.1	10.3	6.2	2.4
pH	7.5	6.9	7.4	9.0
Sand (g kg^{-1})	293	289	718	-
Silt "	267	252	113	-
Clay "	440	459	169	-
Texture	Clay	Clay	Sandy Loam	-
Organic Matter (g kg^{-1})	26	75	16	-
NO_3 mg kg^{-1}	32.4	39.8	22.7	-
P mg kg^{-1}	3.2	5.0	3.4	-

*Spoil and topsoil results from Scholl (1982); bottom ash from Gould (1982).

Table 2. Stand density of saltbushes (plants m^{-2}) on coal mine spoils as influenced by surface shaping and amendments (two years after seeding).

Treatment	Fourwing	Shadscale
brown shale spoil		
Furrow	1.40^{a*}	0.10^{a}
Control	0.29^{b}	0.02^{b}
gray shale spoil		
Furrow	0.70^{a}	0.05^{a}
Control	0.11^{b}	0.01^{b}
Basin	0.68^{a}	0.25^{a}
Control	0.58^{a}	0.05^{b}
Ash (incorp.)	0.00	0.00
Topsoil	0.00	0.00
Control	0.00	0.00

*For each experiment, values with the same letter within column are not significantly different (P=0.05).

Table 3. Soil water content (kg water kg^{-1} dry soil) of coal mine spoil (0-0.15 m) as influenced by surface shaping and amendments, 1979.

Treatment	May	July	Oct.
brown shale spoil			
Furrow	0.235^{aA*}	0.124^{aB}	0.089^{aC}
Control	0.159^{bA}	0.105^{aB}	0.080^{aB}
gray shale spoil			
Furrow	0.222^{aA}	0.084^{aB}	0.093^{aB}
Control	0.087^{bA}	0.062^{bB}	0.079^{aAB}
Basins	0.196^{aA}	0.098^{aB}	0.109^{aB}
Control	0.083^{bA}	0.060^{bB}	0.078^{bAB}
Ash (incorp.)	0.151^{aA}	0.066^{aB}	0.080^{aB}
Topsoil	0.141^{aA}	0.042^{bB}	0.102^{bC}
Control	0.107^{bA}	0.076^{aB}	0.097^{bA}

*For each experiment, values with the same lower case letter within columns are not significantly different (P=0.05).

Values with the same upper case letter within rows are not significantly different (P=0.05).